Final Report

to the

National Agroforestry Center
United States Forest Service

Assessment of Riparian Restoration in Agroecosystems: Potential Techniques and Opportunities in Oklahoma

submitted by

Dr. Steven Anderson, Department of Forestry
Dr. Michael Smolen, Department of Biosystems and Ag Engineering
Division of Agricultural Sciences and Natural Resources
Oklahoma State University

1/15/96

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ROCKY MTN. FOREST & RANGE
EXPERIMENT STATION

Assessment of Riparian Restoration in Agroecosystems: Potential Techniques and Opportunities in Oklahoma

Introduction

Previous land use in Oklahoma has had a detrimental effect on riparian zones including removal of vegetation, conversion to agricultural cropping, overgrazing. In many cases where vegetation does exist it has been modified to less desirable species in regards to ecosystem integrity and wildlife habitat. The 1982 National Resource Inventory indicated that over 33,000 miles of streams in Oklahoma were without trees or shrubs. Little information is known about management of riparian zones and specifically about restoration techniques. In order to better serve landowners and natural resource professionals an assessment of riparian conditions and potential tools and opportunities for restoration of riparian areas is needed for proper land management.

The purpose of this project was to (1) establish a field assessment and demonstration site whereby concepts in riparian zone restoration would be implemented and (2) conduct a literature review of riparian management restoration techniques applicable to the assessment site.

Field Exercise

The site

The selected assessment site is a portion of East Roaring Creek, a small stream located in Grady County, Oklahoma near the town of Alex. In general, the stream has a well developed riparian zone, low degree of pool vegetation, stable banks, gravel riffles and a low degree of pool siltation. Because of the overall high quality of the stream it has been designated as an ecoregional reference stream. Unfortunately, some areas along the stream have been cropped up to the stream banks. Riparian vegetation removal and overgrazing has resulted in stream bank destabilization, siltation and elimination of shade cover.

The site is nearly level consisting mainly of a Port silt loam. It is located on a floodplain that is occasionally flooded for brief periods on the spring and fall. The soil is moderately permeable and available water holding capacity is high. The site is located within the Rolling Red Prairie land resource region receiving between 20 and 30" of precipitation annually. The Rolling Red Prairie region covers 25,400 square miles in Oklahoma, Kansas and Texas. Natural woody riparian vegetation in the area includes, black walnut, eastern cottonwood, green ash, american elm, hackberry, western soapberry and black willow.

Site establishment

Gully mitigation and stream bank stabilization had previously been accomplished on the site by the Oklahoma Conservation Commission and the Grady County Conservation District. The current project focused on restoring the riparian forest vegetation on the site, especially areas that had been cropped to the stream bank.

To successfully accomplish the project a team of partners was established including the landowner; the lessee of the land; the Oklahoma State University (OSU) Extension Forestry, Wildlife and Aquaculture Program in the Department of Forestry; the OSU Department of Biosystems and Agricultural Engineering; the Grady County Extension Center; the Oklahoma Conservation Commission; the Grady County Conservation District; the Oklahoma Department of Agriculture (ODA)-Forestry Services and the Grady County 4-H program. Correspondence and agreements related to the cooperative efforts are attached in the Appendix.

The planting areas were located along East Roaring Creek on a portion of the E 1/2, NE 1/4, Section 2, Township 4 North, Range 6 West. All seedlings were provided by the ODA-Forestry Services except for the cottonwood and willow cuttings which were collected by OSU and ODA-Forestry Services within two weeks prior to the planting. Cuttings and seedlings were I cold storage at the ODA-Forestry Services Forest Regeneration Center until the day of planting.

Two general areas were planted. Areas within the stream banks, which included some steep slopes and some riparian benches, were hand planted with 600 black locust and 200 bald cypress seedlings and 950 cottonwood and willow cuttings. Tree spacing was variable but approximated a 6X6 foot spacing. Areas above the stream banks were primarily machine planted with 900 black walnut, 100 pecan, 200 mulberry, 250 bur oak, and 250 shumard oak seedlings at an approximate spacing of 8X8 feet (see map). A weed fabric was subsequently laid down over these rows for weed control. A total of 3,450 seedlings and cuttings were planted.

Machine planting was accomplished by the lessee using his tractor; ODA-Forestry Services and OSU students and faculty. Hand planting was accomplished by ODA-Forestry Services personnel ; OSU students and faculty; 20 Grady County 4-H students; Grady County Extension Center personnel and the Grady County Conservation District personnel. The Grady County 4-H students also came for a second educational visit to watch the application of the weed barrier.

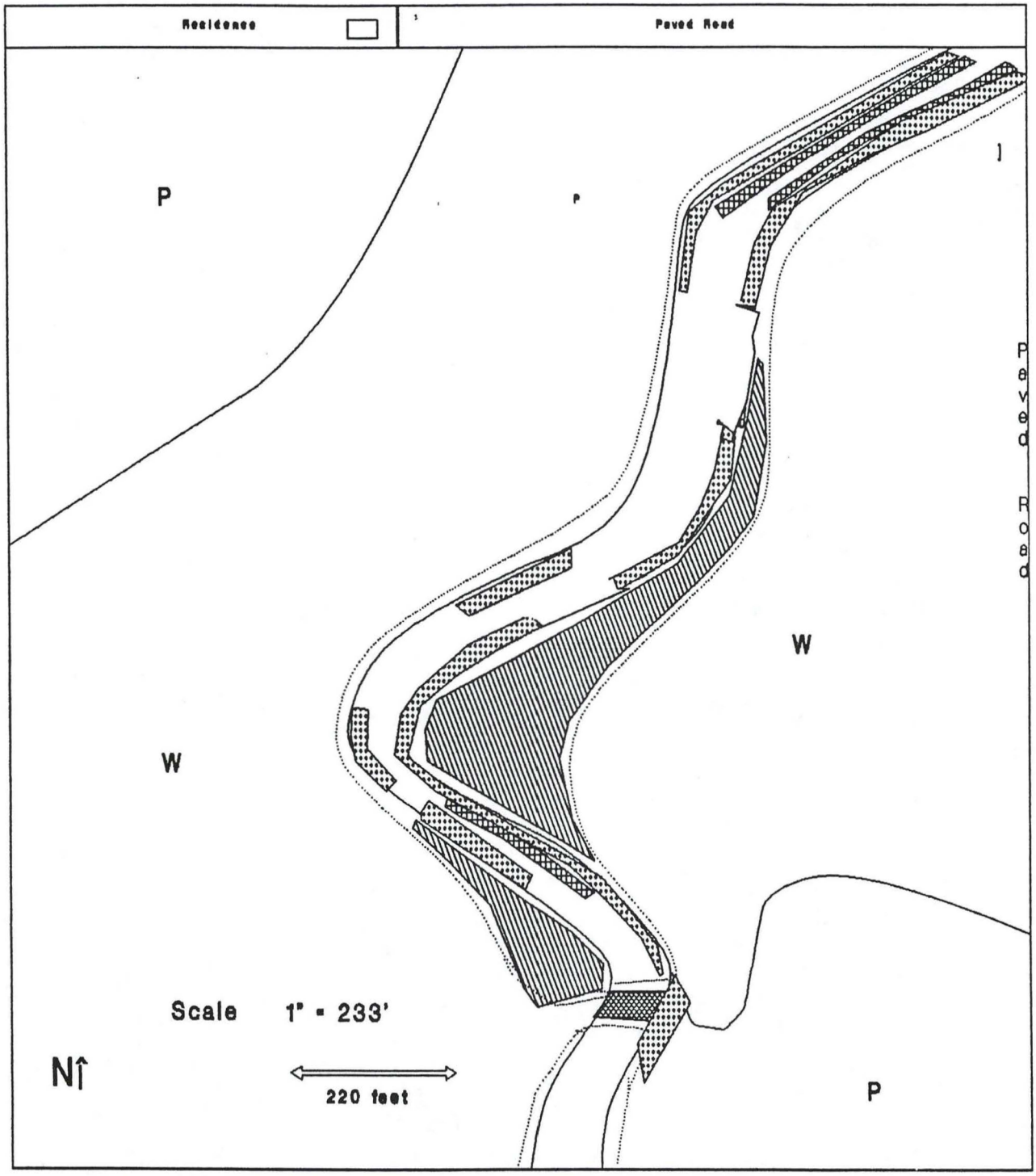
An informal survival check was made during the late summer 1995 indicating an approximate 80 to 90 percent survival rate. However, this was made prior to a late fall drought which affected most of Oklahoma. A more formal survey is expected to be accomplished following leaf out during the Spring 1996.

As part of the assessment site, the Oklahoma Conservation Commission coordinated the electric fencing of the stream bank areas and provided for a cattle crossing with a water guard as per the land lessee's wishes. This protects the planted areas from cattle grazing and limits the cattle access to the stream to a very small area.

The property is bordered on two sides by a paved road so access is excellent to the site. An interpretive sign was placed at a corner site near the paved road (see map). In addition to providing for an educational experience for 4-H youth the demonstration area was the site of a Legislative Awareness Tour organized by the Grady County Conservation District. Both the Oklahoma Conservation Commission and the Grady County Extension Agent discussed the effort with legislators.

Literature Review

A literature review of existing information restoration techniques for riparian areas in Oklahoma focusing on the land resource area represented by the selected assessment site was conducted. The proposed project will also contribute to the data base for another effort entitled "Management Program for Riparian Wetlands to Protect Water Quality", an EPA funded project to develop technical guidelines for riparian protection measures and establish standards for protection of stream banks and riparian wetlands.



Roaring Creek Riparian Restoration Area

Legend

- Fence
-] Interpretive sign
- W Wheat
- P Pasture
- Cattle crossing
- Mixed Hardwoods
- Willow and Black Locust

Appendix A.

MEMORANDUM OF UNDERSTANDING

between

D. F. Robertson

and

Oklahoma State University

This MEMORANDUM OF UNDERSTANDING, made and entered into this Month September Day 1 Year 1994. by and between D. F. Robertson hereafter referred to as demonstration participant and Oklahoma State University, hereafter referred to as OSU, hereby agree to the following concerning application of demonstration project (s) on land owned or administered by the demonstration participant.

The demonstration participant agrees to:

1. Grant permission to design, develop and establish a conservation forestry/agroforestry demonstration project on the participant's land.

   Legal Description: East Half of the Northeast quarter (E1/2-NE1/4) of Section 2, Township 4 North, Range 6 West, Indian Meridian, Grady County, Oklahoma.

2. Grant permission for an interpretive sign to be placed on or near the demonstration site.

3. Grant permission for public access when OSU or it's agent desires to use the demonstration site for technology transfer (e.g. workshops, tours, field days).

4. Maintain the demonstration site to the degree outlined in a mutual agreeable maintenance plan for the duration of 10 years.

5. Protect the demonstration site from damage by grazing animals, fire and other destructive agents that are under the participants control for the duration of 10 years.

OSU agrees to:

1. Limit the use of the site to research, technology transfer, education, promotion and public awareness activities.

2. Construct, place and maintain an interpretive sign listing credits for all major cooperators.

Steve Anderson 9/1/94
Project Investigator Date

Michael Sale 9/1/94
Project Investigator Date

Ray Campbell (for) 9/2/94
C.B. Browning, Dean Date
and Director

Dorothy F. Robertson _____
Demonstration Participant Date Aug. 18, 1994
Dorothy F. Robertson, Trustee
Robertson Family Trust

MEMORANDUM OF UNDERSTANDING

between

G.T. PARKS

and

Oklahoma State University

This MEMORANDUM OF UNDERSTANDING, made and entered into this Month AUGUST Day 3 Year 1994. by and between G.T. PARKS hereafter referred to as demonstration participant and Oklahoma State University, hereafter referred to as OSU, hereby agree to the following concerning application of demonstration project (s) on land owned or administered by the demonstration participant.

The demonstration participant agrees to:

1. Grant permission to design, develop and establish a conservation forestry/agroforestry demonstration project on the participant's land.

   Legal Description: East Half of the Northeast quarter (E1/2-NE1/4) of Section 2, Township 4 North, Range 6 West, Indian Meridian, Grady County, Oklahoma.

2. Grant permission for an interpretive sign to be placed on or near the demonstration site.

3. Grant permission for public access when OSU or it's agent desires to use the demonstration site for technology transfer (e.g. workshops, tours, field days).

4. Maintain the demonstration site to the degree outlined in a mutual agreeable maintenance plan for the duration of 10 years.

5. Protect the demonstration site from damage by grazing animals, fire and other destructive agents that are under the participants control for the duration of 10 years.

OSU agrees to:

1. Limit the use of the site to research, technology transfer, education, promotion and public awareness activities.

2. Construct, place and maintain an interpretive sign listing credits for all major cooperators.

Steven Anderson 8/3/94
Project Investigator Date

G. T. Parks 8/3/94
Demonstration Participant Date

Mike Smylen 8/3/94
Project Investigator Date

C.B. Browning 8-4-94
C.B. Browning, Dean Date
and Director

OKLAHOMA DEPARTMENT OF AGRICULTURE

Gary L. Sherrer
Commissioner
Secretary of Agriculture

Charles W. Anderson
Assistant Commissioner

2800 North Lincoln Boulevard
Oklahoma City, Oklahoma 73105-4298
(405) 521-3864

David Walters
Governor

November 28, 1994

Steve Anderson, Extension Forester
OSU Department of Forestry
008C Ag Hall
Stillwater, OK 74078

Dear Steve:

As a followup to our visit to the riparian demonstration area near Alex, Forestry Services is willing to contribute the following to the completion of the project:

1. Tree seedlings from the Regeneration Center will be furnished at no cost to complete the riparian area planting.

2. Bob Harrel agreed to provide you a summary of estimated seedling needs by species, and help locate nearby cottonwood/willow cutting sites.

3. We will provide our machine to lay down the mulch fabric. It would be helpful if Mr. Parks could provide the tractor.

4. I would imagine one or more of us would be available to help with the planting, schedules permitting.

We believe the project will be a useful demonstration of the feasibility and value of restoring riparian vegetation along denuded drainages in central and western Oklahoma. Because this is a demonstration, we need to consider low-tech/low-cost approaches which will be attractive to private landowners.

Sincerely,

Kurtis L. Atkinson

Kurtis L. Atkinson, Assistant Director
Forestry Services

cc: Al Myatt, Bob Harrel, Pat McDowell

M E M O R A N D U M

To: Steve Anderson, Kurt Atkinson

From: Bob Harrel

Date: December 7, 1994

Re: East Roaring Creek Riparian Area

The East Roaring Creek riparian area is located in NE, Section 2, T 4 N, R 6 W. The concept of the project is to restore creek side vegetation for erosion control purposes. Cattle panels with willow reinforcement are needed in some locations to stabilize existing erosion. Tree planting will be used both on the rim and stream bank to reduce erosion. The rim planting will help to provide travel ways for deer, turkey and other wildlife. Cattle are limited to one low percent grade crossing to reduce cutting and breakdown of the stream bank. This crossing is designated and fenced to control cattle movement. Fencing is required in the entire area to protect the tree seedlings and stream sides. Grazing will be allowed at selected periods of dry weather but not during rainy or wet weather. Soils in the planting area are Pulaski fine sandy loam and are excellent for planting. Estimated cost are listed on page 2. (See Table of Costs)

It is expected to plant two rows of trees along each rim of the creek to help heal active bare areas. These seedlings should be planted at 12 feet by 12 feet spacing with 302 trees per acre. A mixture of tree species are needed for better wildlife habitat and food sources. The tree mixture also provides additional reduction of risk from insects and diseases. By using a dot grid, it was found that 6.85 acres of tree planting are required on the rim for a total of 2100 trees. Fiber mat is needed for increased survival and reduced competation. It is expected we need 12,000 feet of fiber mat. Fencing with gates is another component that is needed for best survival. Mowing between rows reduces vegetation competation. You need the following species and numbers to adequately plant the rim area: black walnut 500, pecan 300, green ash 300, mulberry 300, cottonwood 500, bur oak 200, and shummard oak 100.

The active stream bank erosion and bare areas should be planted at 6 feet by 6 feet spacing. The number of acres to be planted is 2.925 acres and 3500 seedlings. The species needed are willow 1000, black locust 2000, cottonwood 200, and cypress 300 in the stream bottom. The cottonwood and willow will come from cuttings adjacent to the area. The cutting size needed is 3/4 inch or less and at least two feet long. The cuttings require soaking for 24 hours before planting. The best time to collect the

cuttings is during dormant periods, just before bark slippage or bud break.

Pipes are used to drain the fields but do not reach the streambed. These pipes require extension and cattle panels in the active erosion areas to stop undercutting. Cattle panels are needed at the area of active undercutting banks with the associated bank slippage.

TABLE OF COSTS

ITEM	COSTS
2100 Seedlings for rim furnished by Okla Forestry Services	
3500 Seedlings for streambanks furnished by Ok Forestry Services	
12,000 feet Fiber Mat 24 500' rolls @ $128.50 per roll	$3,084.00
Cattle Panels 20 @ 9.00 per panel	$180.00
Metal "T" posts 60 @ 3.00 per post	$180.00
Mechanical tree planter furnished by Okla Forestry Services	
Fabric laying machine furnished by Oklahoma Forestry Services	
50-60 horsepower tractor furnished by lessee	
Labor with associated tools for cutting cottonwood and willow cuttings furnished by Okla State Extension Service	
Hand planting furnished by Okla Pardon and Parole/Okla State Extension Service	
Supervision of planting crew provided by Okla Conservation Commission	
Mowing done be lessee tractor and mower furnished by lessee	

MASON MUNGLE
EXECUTIVE DIRECTOR

BEN POLLARD
ASSISTANT DIRECTOR

STATE OF OKLAHOMA
OKLAHOMA CONSERVATION COMMISSION

December 21, 1994

Steve Anderson, Department of Forestry
Division of Agricultural Sciences and Natural Resources
Oklahoma State University
Department of Forestry
008C Agriculture Hall
Stillwater, Oklahoma 74078-0491

Dear Mr. Anderson:

I have reviewed my East Roaring Creek Riparian Corridor Restoration Project plan and made budget adjustments. As an extension of this EPA Wetlands Demonstration Project I can make available $1,000 for construction of 3000 feet of fencing on East Roaring Creek . The estimated amount of materials are as listed:

Items	No.	Unit Cost	Cost
Corners (7"x 8')	40	$12.80	$512.00
Braces (3½"x 6½')	30	3.25	97.50
Posts (Steel Ts)	200	2.15	430.00
Wire (2pt 12½ Gauge)	12	33.50	402.00
		Total	**$1441.50**

This estimate was made without the consideration of moving the existing fencing. This is material cost only and on the high side for estimation. Hopefully, labor may be furnished by the landowner and inmate labor through the assistance of Mr. Tom Parish, Department of Corrections. I will consult with Dee Surber, Grady County Conservation District if any assistance can be contributed on their behalf. I feel confident that this fencing project can be completed within this cost estimate. If you have any questions or further concerns you may contact myself or Dee Surber.

Sincerely,

Derril Putman
Wetlands Program Manager

Copies: Mason Mungle, Executive Director
Ben Pollard, Assistant Director
Dan Sebert, Director, District Operations
Dee Surber, Programs Director , Grady County C.D.

Oklahoma Cooperative Extension Service
Division of Agricultural Sciences and Natural Resources
Oklahoma State University
Department of Forestry • 008C Agricultural Hall
(405) 744-6432 • Stillwater, Oklahoma 74078-0491

February 28, 1995

Ron Justice, Extension Director
Grady County Extension Center
828 Choctaw
Chickasha, OK 73018

Dear Ron:

This letter is to confirm our plans for tree planting on March 15, 1995 on the Riparian Restoration Demonstration Area located in Grady County. My understanding is that you will be bringing 50 to 60 4th, 5th and 6th grade students to participate in the project on that day. Please confirm with me as soon as possible how many students may be able to participate; what their general schedules might be during the day and how many adult leaders/teachers might accompany them.

We will be planning to arrive the evening of February 14, 1995 so we can get an early start in the morning to set-up. I suggest that we should plan on the students arriving about 10:00 am. They should bring a lunch or have transportation to where they can have lunch. Because this is our first attempt at such a project we are not quite sure how long all of the planting may take.

I have attached a one-page summary of the project that you can share with the school administration, teachers and students. Please let me know if you would like it modified in any way before you send it out. Everyone should be advised to be prepared for poor weather (boots, jackets, work gloves etc.) and that some planting may be done within the streambanks so rubber boots may be required. Your leadership on this project at the local level is much appreciated. I would ask that you keep Dee Surber informed of our schedules and plans as the planting date draws near and confirm that she has contacted the Lessee regarding our planting date. I am trying to arrange for Sunup to come down for a news story. Please feel free to invite any other local newspapers or television stations.

Thanks for your help on this project. I'm looking forward to it.

Sincerely,

Steve

Dr. Steven Anderson
Associate Professor of Forestry

justice.doc

RIPARIAN RESTORATION DEMONSTRATION AREA
EAST ROARING CREEK
GRADY COUNTY, OKLAHOMA

Although there has been increased attention given to water quality and nonpoint source pollution, there has been little attention given in Oklahoma to management of riparian areas; those areas adjacent to streams, rivers and lakes. However, our concept of water quality is rapidly changing from a focus on water quality to management of stream health and habitat. This approach puts much more emphasis on the previously neglected riparian portion of the watershed.

Previous land-use has had a detrimental effect on riparian zones by removing vegetation; conversion to agricultural crops; and overgrazing. In many cases, where vegetation does exist it has been modified to less desirable species in regards to ecosystem integrity and wildlife habitat. The 1982 National Resources Inventory indicated that over 33,000 miles of stream in Oklahoma were without trees or shrubs.

The purpose of this project is to demonstrate restoration of the riparian vegetation along a portion of East Roaring Creek, located near the town of Alex, Oklahoma. The owners of the land live in Tulsa but the land is presently leased for cattle production. Present practices include the planting and grazing out of winter wheat. Because of severe gullying, the Oklahoma Conservation Commission worked with the landowner/lessee to reconfigure some of the streambank and then fence off critical areas from livestock. Approximately 5,200 trees will be planted including oak; black walnut, cottonwood, willow and black locust. Trees above the streambank will be planted and then followed by the machine application of a plastic weed barrier. Araes within the streambank will also be planted to control erosion. Extended fencing will be used to protect the tree plantings and provide for livestock crossing with limited access to the stream and riparian areas.

It is expected that students will gain a greater knowledge about riparian forest buffers, their function in the ecosystem and affect on water quality, wildlife habitat and diversification of farm enterprises. Handouts on forestry and water quality, riparian forest buffers and bst management practices will be provided to all students and teachers.

Potential Schedule

10:00 am	Students arrive
10:10 am	Introduction to Water Quality and Restoration Project - Steve Anderson, OSU
10:40 am	Instruction on Tree Planting
11:00 am	Visit and participate in tree planting and weed barrier machine
12:00 pm	Lunch
1:00 pm	Continue tree planting
3:00	Adjourn

05-10-95
Chickasha Star

GRADY COUNTY Conservation District Personnel Mike Box and Dee Surber assist OSU Extension Forester Steve Anderson in weed barrier application on East Roaring Creek riparian project. A total of 3,100 tree seedings have been planted to improve bank stabilization and water quality.

Riparian Restoration Area Established

Through research and education, the value of wetlands is being brought to the attention of the public. Because there are approximately 1,000 acres of designated wetland area in Grady County, management and protection can best be accomplished when integrated with other conservation and water quality programs. East Roaring Creek has been chosen as one of three projects in the State Wetland Development Grant. Unlike most steams in Oklahoma, it has a well developed riparian zone, vegetation, stable banks, and a low degree of siltation. Unfortunately, the high quality of treatment afforded to the stream does not extend for its entire length. Below a defined stream segment, the riparian area has been removed resulting in bank destabilization and siltation. To ensure that this stream remains a good reference point for water quality and improved wildlife habitat, riparian restoration has begun.

Trees are important to protect water quality and stabilize stream banks according to Steven Anderson, Extension Forestry Specialist, Oklahoma State University. Extending the riparian forest buffer where lands have been cropped to the stream bank is one of the most important measures farmers can take he added.

Anderson is one of thirty people from various agencies who is assisting in the riparian restoration on the property owned by Robertson Family Trust and operated by G.T. Parks, Alex. Approximately 3,100 tree seedlings were planted above the stream bank. Species include walnut pecan, ash, mulberry, shumard oak and bur oak. Within the stream bank seedlings including black locust, willow, and bald cypress were planted.

Most recently, weed barrier was rolled down on the trees. The weed barrier not only controls weed competition, but also conserves soil moisture during the summer months. This procedure has been shown to dramatically improve tree survival.

agencies involved in the riparian project include Grady County Conservation District, Grady County OSU Extension, Oklahoma Cooperative Extension Service, Oklahoma Forestry Service, Oklahoma Conservation Commission (EPA Wetlands Protection Grants), USDA Forest Service (Center for Semiarid Agroforestry), U.S. Fish and wildlife, and the USDA Natural Resource Conservation Service.

The Oklahoma Association of Conservation Districts

and

the Grady County Conservation District

invite you to be our guest on a
Wetland Awareness Tour

WHEN: *Friday, April 7, 1995*

TIME: *2:00 - 6:00 p.m.*

EVENTS:	*2:00 p.m.*	*Grady County Fairgrounds*
	2:30-4:00 p.m.	*East Roaring Creek Riparian Restoration* *Ninnekah Permanent Outdoor Classroom* *Partners for Wildlife Project*
	4:00 - 5:30 p.m.	*Social Hour & Cook Out*
	5:30 - 6:00 p.m.	*Closing Remarks*

WHERE: *meet at the Grady County Fairgrounds*
(map attached)

Bring a heardy appetite for Ralph's famous smoked ribs and brisket. A good time is guaranteed!

RSVP

Casual Dress

EAST ROARING CREEK
RIPARIAN RESTORATION AREA

COOPERATORS:

- ROBERTSON FAMILY TRUST
- G.T. PARKS
- CENTER FOR SEMI ARID AGROFORESTRY – USDA
- OK COOPERATIVE EXTENSION SERVICE
- GRADY COUNTY CONSERVATION DISTRICT
- OK CONSERVATION COMMISSION
- OK DEPT. OF AGRICULTURE – FORESTRY SERVICES
- U.S. ENVIRONMENTAL PROTECTION AGENCY
- U.S. FISH AND WILDLIFE SERVICE

Literature Review

Assessment of Riparian Restoration in Agroecosystems: Potential Techniques and Opportunities

April 2, 1996

Submitted by

Spencer Scoles
Research Associate

Steven Anderson
Professor of Forestry
and
Michael Smolen
Associate Professor of Biosystems and Ag Engineering
Oklahoma State University
Stillwater, Oklahoma

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INTRODUCTION

Riparian areas or zones are areas supported by a high water table because of proximity to surface or subsurface water. Riparian areas are considered to be those areas of streamside vegetation along perennial or intermittent streams, including the streambank and adjoining flood plain. Riparian zones are characterized by distinct soils and support more productive and diverse plant communities and animal species than adjacent more xeric upland areas (Brinson et al., 1981).

High vegetation species diversity, productivity, and proximity to open water are the basis for the myriad of uses for riparian zones. Near the water level, vegetation stabilizes stream channels by creating a rough surface that reduces stream velocity, while roots hold bank material together (Platts, 1979; Heede, 1977). During high flows that exceed the streambanks, riparian zones retain the sediment and nutrients from upland pollution sources such as agricultural fields. When rainfall exceeds infiltration rates, riparian vegetation provides a buffer that slows and dissipates the energy of overland flow, even as root systems intercept and absorb the nutrients in subsurface flow (Lowrance et al., 1985).

High water quality promotes diverse aquatic habitat and this improves fisheries (Cummins, 1974). Riparian habitat value to wildlife is well documented. Increased edge effect for area occupied (Odum, 1978) and high structural diversity of plant communities are typical of riparian zones (Anderson et al., 1983). In addition, succulent vegetation, access to water, and shade make riparian zones attractive to livestock (Kauffman and Kreuger, 1984; Armour et al., 1990).

Although many people have come to recognize the value of riparian zones, these areas are still threatened (Stevens et al., 1977). The most common threats to riparian zone health in the Southern Great Plains are uncontrolled grazing, conversion to cropland, flood control, stream channelization, and groundwater decline.

The direct physical effects of concentrated livestock use include removal of vegetation along streambanks; prevention of growth of woody species; bank collapse from weight of livestock; chiseling of banks by hooves; and soil compaction (Blackburn and Wood, 1991; Armour et al., 1990). These actions can increase erosion which may lead to stream channel widening or downcutting (Schmidly and Ditton, 1978; Meehan and Platts, 1978). Major effects

on fish habitat include reduction of shade, increased stream temperature, streambed sedimentation, and reduced fool supply (Armour et al., 1990). Recovery of stream channels, aquatic habitat, and riparian vegetation after livestock have been removed has been demonstrated (Platts, 1981; Kauffman et al., 1983; and Chaney et al., 1990)

Channelization, the straightening and relocation of streams, facilitates the clearing, drainage, and subsequent farming of bottomland areas (Patrick, 1973). The channel deepening and downcutting that occurs in a channelized stream also may lead to a drop in the water table and subsequent shrinkage in the width of riparian zones as xerophytes replace more mesic forest species (Barclay, 1978). Flood control impoundments provide flood protection to portions of streams and allows agricultural activities to take place in the flood plains of streams.

The negative effects of groundwater decline are well documented (Campbell and Green, 1968; Gutentag at al., 1984). Most native riparian vegetation tends to develop relatively shallow root systems that are unable to reach water in areas of low groundwater.

Channelization, clearing for agriculture and reservoir construction have altered a significant proportion of Oklahoma's original riparian habitat. In a study of two third-order tributaries of the Washita River, Barclay (1980) noted a 93 and 84 percent reduction in riparian habitat since European settlement. The loss of riparian habitat also eliminated many species of plants and animals from areas they once occupied. Even where forests remain intact, some plant and animal species have been eliminated. In western Oklahoma, Stinnett et al. (1987) estimate that only 22-28 percent of 621,000 acres of potential riparian habitat are presently occupied by forests. They estimate that the amount of wetlands in the Canadian River floodplain decreased from 53 percent in 1954 to 33 percent in 1984. Losses were attributed to conversion of floodplain land to crop and livestock production.

In 1995, a riparian restoration project was established on East Roaring Creek, a tributary of the Washita River in Grady County, Oklahoma. This report describes the riparian zone restoration techniques common to the Southern Great Plains and the methods for assessing the success of restoration projects. The project was supported by the USDA Forest Service National Agroforestry Center. As part of the project a review of restoration techniques was requested.

RIPARIAN RESTORATION TECHNIQUES

The goal of restoration is to reduce the intensity, magnitude, or frequency of human impacts in order to improve water quality or riparian habitat. Restorationists recommend that before restoration strategies are employed, the influences of upland land uses should be addressed (e.g. the application of upland soil erosion treatments such as terraces, grass waterways, and minimum tillage); that the causes of riparian zone degradation should be identified (e.g. groundwater decline, competition from animals and non-native plants); and that methods of treatment should be designed to either address the cause of site degradation or overcome its symptoms (e.g. irrigation and species selection, weed control, and improved grazing schedules). This report provides a review of restoration techniques based on three strategies — improving riparian cover, streambank stabilization, and in-channel habitat improvements. A brief treatment of grazing management is included.

IMPROVING RIPARIAN COVER

The riparian zone of a stream will intercept and store sediment-bound nutrients in surface runoff and absorb soluble forms of nutrients and agricultural chemicals in surface runoff and subsurface water. In small to mid-size streams, riparian vegetation moderates stream water temperature and provides terrestrial habitat for wildlife.

Improving riparian cover involves planting trees, shrubs, forbs, and grasses in degraded riparian ecosystems. The characteristics of riparian vegetation that are important to restoration efforts are width, vegetation type, species composition, and structure required to achieve the water quality or terrestrial habitat improvement objectives defined in the restoration plan.

Moderating Stream Temperatures

The temperature of running waters varies on seasonal and daily time scales. Seasonal changes in water temperatures in rivers generally follow seasonal trends in mean monthly air temperature. Daily temperature fluctuations are common in small streams, especially if unshaded, due to day versus night changes in air temperature and absorption of solar radiation during the day.

The principle source of heat for small streams is solar radiation. Stream temperature is dependent on the width, length, composition, and density of trees in the riparian zone. Shade removal may increase solar radiation loads by six to seven times (Brown, 1969). However, where groundwater inputs to the stream are important, shading may be a secondary factor determining stream temperature. Groundwater temperature is usually within 1 °C of the mean annual air temperature and is not influenced by streamside shading. Stream pools that have large groundwater inputs often exhibit a vertical thermal stratification while pool temperature where groundwater inputs are absent are nearly homogeneous.

In addition to groundwater inputs, the volume of streamflow, stream surface area, and streambed may modify the effect of solar radiation on stream temperature. These factors should be considered when comparing reported temperature changes after vegetation removal. Small streams (low streamflow) heat up faster than larger ones. Because of surface area exposure to the sun, a wide, shallow stream will heat up faster than a narrow, deeper stream with the same discharge. In small clear streams with rocked bottoms, up to 20% of the incident heat can be absorbed. This tends to lower the peak temperature and broaden the daily temperature profile as the bed becomes a source of heat at night.

Research

Shading by the riparian canopy moderates seasonal temperature extremes resulting in lower maximum values in summer and higher minimum values in winter (Karr and Schlosser, 1978). Shade is also effective in reducing daily high water temperatures and diminishing daily temperature fluctuations. Karr and Schlosser (1978) showed that weekly maximum temperatures in cropland ranged from 5.0 °C to 12.8 °C above those of a nearby forested stream. Riparian zone width between 10-30m have been shown to maintain normal stream temperatures (Aubertin and Patrick, 1974, Corbett et al., 1978, Lynch and Corbett, 1990).

Riparian Zone Design Considerations for Controlling Water Temperature

If the prairie stream is of value as a warm water fishery, then an acceptable temperature range must be maintained. Predicting the effect of partial or complete shade removal on the

temperature of the stream would be helpful. Brown (1970) presented the following equation for estimating temperature change as a result of complete removal:

$$T = (A)(H/D)(0.000267)$$

where ρT is the temperature change expected in °F, A is the stream surface area in square feet, H is the heat load in BTU/ft^2/min, and D is the stream discharge in cfs. Predicting the effect of partial removal of the riparian canopy is more difficult, however.

If stream temperature is determined to be an important factor in a restoration project, then decisions concerning riparian zone width structure and vegetation density will depend on the type of stream being protected. A small stream would require less vegetation to shade it than does a large stream — brush species may be just as effective in providing shade as overstory trees. A spherical densiometer can be used to measure the amount of sunlight incident on the stream (Platts et al., 1987). If a dense, wide riparian zone is present, one can determine which vegetation can be removed without changing the shading function of the riparian canopy.

Controlling stream temperature may also require extending the riparian zone above the stream section of interest. Research has shown that a heated stream may not cool (Brown, 1970). As the heated water flows downstream through the protected area, heat loss by convection, evaporation, and conduction is not enough to compensate for the heat gained upstream through radiation inputs.

Where two tributaries meet or where there is mixing with groundwater, the impact on temperature can be estimated using a "mixing ratio" weighted by discharge. This can be written as

$$\text{Adjusted Temperature} = \frac{F_m T_m + F_t T_t}{F_m + F_t}$$

where F_m and T_m are the flow and temperature of the main stream and F_t and T_t are the flow and temperature of the tributary or groundwater input (Brown, 1969). This makes it possible to predict how changes in riparian zone management in other parts of the watershed will affect stream temperature at a downstream site of interest.

Sediment and Nutrient Removal

Research

Riparian zone vegetation slows surface runoff and traps sediment. Roots restrain soils from eroding. Castelle's et al. (1994) review indicates that 23-61m wide riparian zones can reduce sediment input to surface waters by 33-90%. Dillaha et al. (1989) demonstrated that narrow (4.6m and 9.2m) grassed filter strips removed 70 and 84% of suspended solids from agricultural runoff. The effectiveness of riparian zones as a sediment filter depends on the maintenance of sheet flow (Dillaha et al., 1986). By the time surface runoff gets to the riparian zone, however, it may be channelized and have sufficient velocity to keep much of the sediment in suspension. This is of special concern in the southern Great Plains on sites susceptible to gullying. Even if suspended sediments are deposited in the riparian zone, the sediment can be moved to the watercourse during a subsequent, larger storm event.

The methods of nutrient (and agri-chemical) removal in riparian zones includes plant and microbial uptake and the adsorption of nutrients to soil and organic matter particles. For plants to be effective at removing nutrients from subsurface waters, the water table must be at least as high as the plant rooting depth or there must be a large component of unsaturated flow. Forested riparian zones 30-50m wide reduced nitrate concentrations in surface and subsurface waters 79-98% and 40-100% respectively (Osborne and Kovacic, 1993). Forested riparian zones 16-50m wide have reduced total phosphorus in surface runoff by 50-85%. For grassed riparian zones, nitrate concentrations decreased 10-60% in subsurface water and 54-84% in surface runoff. Phosphorus concentrations in surface runoff were reduced 61-83%. Research of phosphorus reduction in subsurface waters has not shown a clear trend. The data of Chescheir et al. (1991); Cooper and Gilliam (1987); Gilliam (1994); and Peterjohn and Correll (1984) suggest that riparian zones are adequate for removing phosphorus attached to sediment, but are relatively ineffective in removing dissolved phosphorus.

Direct comparisons of the efficiency of nutrient removal between forested and grassed riparian zones have not been made. However, a general trend in all research has shown that nutrient removal efficiency increases with the width of the riparian zone (Peterson et al., 1992). Species composition will also affect nutrient removal efficiency. The use of deep rooted species such as Poplar may be especially attractive as they have the potential to reduce nitrogen in the soil

profile and in near-surface groundwater (Licht and Schnoor, 1990; O'Neil and Gordon, 1993). To this end, a listing of southern Great Plains plant species based on biological uptake of nutrients should be developed. Current species recommended for erosion control in Oklahoma are presented in Table 1.

The long-term effectiveness of riparian zones as sediment and nutrient filters has been questioned (Osborne and Kovacic, 1993; Dillaha et al., 1986, 1989; Gough, 1988). Sediment accumulation in the litter layer, rapid surface runoff in microchannels, and a large subsurface flow component through macropores may contribute to declining effectiveness through time. Cooper et al. (1987) and Lowrance et al. (1988) have suggested that forested riparian zones can filter sediments over long periods. Magette et al. (1989) and Dillaha et al. (1989) indicate that grassed buffer strips may have short sediment filtering lives and that sediment accumulation along the edges of the riparian zone and in areas of concentrated channel flow would have to be removed. Cooper et al. (1986) and Osborne and Kovacic (1993) have both reported that nutrients can be released from the riparian zone during periods of high runoff. Osborne and Kovacic (1993) suggest that maintaining riparian vegetation at an intermediate successional stage would maximize nutrient removal efficiencies.

Riparian Zone Design Considerations for Sediment and Nutrient Removal

For sediment and nutrient removal, width and plant species composition are the major design elements of a riparian zone. Wider riparian zones are needed as the slope or intensity of land use increases, or as soil permeability decreases (Schultz et al., 1991). However, riparian zones that are larger than needed unnecessarily constrain the use of the land. Castelle et al. (1994) identified four criteria for determining riparian zone width: (1) functional value of the stream, (2) intensity for adjacent land use, (3) riparian zone characteristics, and (4) the functional requirement for the riparian zone. Generally, narrower widths are appropriate when the stream is of relatively low functional value, adjacent land use has low impact potential, and the riparian zone is in good condition with dense vegetation and undisturbed soils.

Species composition choices are dependent on the expected extent of surface runoff and overbank flows. Schultz et al. (1991) describe a multi-species riparian buffer strip (MSRBS) design developed for the agricultural and grassed landscapes of the Great Plains. The MSRBS is

composed of three zones - a zone of rapidly growing trees (willow, cottonwood) nearest to the streambank, followed by a zone of trees and shrubs, then a strip of native warm-season grasses. The trees and shrubs in zone 2 provide perennial root systems and long-term nutrient storage close to the stream. The trees in zone 1 reinforce the streambank and provide shade and a detrital food source for aquatic organisms. Shrubs contribute a higher density of stems to slow flood flows. The vertical structure of such a system provides diversified wildlife habitat. The grasses function to intercept surface runoff, trap sediment, and absorb nutrients. The annual turnover of grasses improves soil infiltration capacities and stimulates microbial growth. Native tall-prairie grasses are recommended instead of the cool-season grasses used for grassed waterways.

Terrestrial Wildlife Habitat Improvement

Riparian ecosystems are valuable to wildlife as a source of water, food, and cover. Increased edge effect, vegetative composition, diversity, and structural complexity are characteristic of riparian areas that support diverse wildlife species. Riparian areas often have a "double edge effect," with one side of the forest bordering the stream and the other bordering an area that may have been cleared for agriculture. Plant species diversity is often high within a streamside forest because of this edge effect. Species diversity is also favored if the riparian area is wide enough to include a range of elevations. Higher levels of structural complexity are associated with high species diversity and edge effects. Vegetation height and arrangement of trees, shrubs, grasses and forbs, and groundcover influence the habitat value of riparian areas by providing a variety of wildlife foods, dens, roosts, and nesting sites.

Riparian areas, wetlands and playa lakes, are important habitat for wildlife in the southern Great Plains and in those areas dominated by agriculture, they may be the only extensive natural wildlife habitat remaining (Monda et al., 1993). Riparian and wetland areas in the southern Great Plains play a major role within the Central Flyway by providing critical waterfowl migration and wintering areas. The biomass produced in these fertile areas results in rich biological diversity. For instance, riparian areas in western Oklahoma provide some form of required habitat for 34 percent of the 394 bird species reported in the state, and support at least 28 species of fish, 13 species of amphibians, 43 species of reptiles and 49 species of mammals (Stinnett et al., 1987). Historical loss of these riparian habitats has been extensive (Stinnett et al., 1987; Monda et al.,

1993) while significant changes in vegetation have also been documented (Barclay, 1980; Behnke and Raleigh, 1978; Schmidly and Ditton, 1978; Starkey et al., 1982).

In general, the restoration of riparian lands in the southern Great Plains may provide the most significant opportunity for improvement in wildlife habitat. Erosion control policies that maintain soil productivity and improve water quality tend to enhance upland wildlife habitat (Miranowski and Bender, 1982).

Research

Little research has been done on the impacts of riparian zone manipulation on terrestrial wildlife species. For this reason, suggested approaches to their evaluation are few. In an effort to assess wildlife habitat benefits of agricultural erosion control practices, Miranowski and Bender (1982) suggest habitat indexing and valuation procedures in a linear programming model. In this model the habitat index is derived from evaluations of total acres in a vegetative type, the diversity and distribution of vegetative type and a factor for management of a vegetative type. They assume that (1) greater diversity of vegetative types in a given area provides a more suitable habitat for a particular species as well as for a greater variety of species and (2) interspersion of vegetative types is conducive to wildlife abundance and diversity. Although used to evaluate tillage systems this model may be applicable to discussions regarding riparian use.

One study, examining effects of riparian habitat manipulation in an agricultural setting in Iowa, found that if all woody vegetation were removed from a riparian community but herbaceous cover remained, that 32 of the non-game bird species studied would be eliminated, 5 might decrease in numbers, and 4 would benefit (Stauffer and Best, 1980). Reduction of woody vegetation to narrow strips would provide favorable breeding habitat for 12 species, but densities of 16 species would decline and 6 species would be eliminated. If the tree canopy were only partially removed 22 species would benefit. Shrub or sapling removal would benefit 4 species and be a detriment to 11 species. Snag removal would adversely affect 9 cavity-nesting birds. Their findings agreed with other research showing that bird species diversity is correlated with habitat diversity and that manipulations that increase the structural diversity of the habitat would benefit the greatest number of species.

In a companion study on small mammals Geier and Best (1980) found that timber removal, grazing and stream-channel realignment increased populations of 7 of 9 small mammal species examined. Habitat manipulations such as thinning deciduous trees, reducing the shrub or forb cover and removing woody plant debris would benefit some species while being a detriment to others.

Riparian areas in western arid areas are also critical habitat areas for games species such as turkey and deer (Dickson and Warren, 1993). The use of mixed tree-shrub-grass buffer strips along streams can provide corridors of cover and habitat for wildlife movement (Schultz et al., 1991).

Width of riparian zones needed for particular wildlife species has not been investigated in the southern Great Plains; however, a study in the forested portion of eastern Texas found that streamside management zone width significantly influenced the abundance of amphibians and reptiles within the streamside zone. There were fewer amphibians and reptiles in narrow 0 to 25 meter streamside zones than in wider zones of 30 to 95 meters (Rudolph and Dickson, 1990). Increased amphibian and reptile populations were associated with a closed canopy and leaf litter ground cover.

Riparian Zone Design Considerations for Wildlife Habitat

Design specifications for riparian wildlife habitat are not well defined and will be dependent on the wildlife species of concern. Elements of design should consider species, structure and width of riparian zones. Species recommended for wildlife plantings and other uses in central and western Oklahoma are presented in Table 1 (ODA-Forestry Services, 1995).

Table 1. Common Uses of Bareroot Tree and Shrub Species in Oklahoma.

Species	Wind-break	Fuel-wood	Erosion Control	Christmas Trees	Livestock Production	Wildlife	Timber, Products	Mine Reclamation
American Plum	X		X			1		X
Amur Honeysuckle	X					1		
Arborvitae	1				X	X		
Austrian Pine	1			1	X	X		
Autumn Olive	X		X			1		X
Baldcypress			X			X	X	
Black Locust	X	1	1			X		X
Black Walnut						X	1	
Bur Oak	X					X	1	
Chokecherry	X		X			1		
Common Lilac	1		X			X		
Cotoneaster	X					1		
Euonymus	X					1		
Fragrant Sumac	X					1		
Green Ash	1	X					X	
Hackberry	1					X		
Lacebark Elm	1					X		
Loblolly Pine	X		X	X			1	X
Mulberry	1	X				1		
Osage Orange	1	X				X		
Pecan (Native)	X					X	1	
Ponderosa Pine	1				X	X		
Redbud	X					1		
Redcedar	1			X	X	X		X
Rocky Mtn. Juniper	1				X	X		
Russian Olive	X		X			1		X
Sand Plum	X		X			1		X
Sawtooth Oak	X					1		
Scotch Pine	X			1		X		
Shortleaf Pine							1	X
Shrub Lespedeza	X		X			1		X
Shumard Oak	X					X	X	
Silver Maple	1					X		
Sycamore	1						X	
Virginia Pine			X	1				
Vitex	X					1		

*Note: "1" = Primary Use(s) "X" = Other Good Uses

Recommended structure (trees, shrubs, grasses) of the riparian zone varies by species; however, the more diverse the structure the more wildlife species will be encouraged. Terrestrial habitat can be enhanced by combining components of the landscape structure. A patch consists of a nonlinear surface differing in appearance from its surroundings. Patches vary in shape, type and

boundary characteristics (Forman and Godron, 1986). Patches are usually embedded in a matrix, a surrounding area that has different species structure or composition. The edge of a patch is distinctly different from the interior. Because it contains species from two or more patches there is greater species diversity. Corridors are narrow, linear strips that differ from the matrix on either side. They serve as important transportation networks for wildlife, often from one patch to another. A restored riparian corridor should incorporate these landscape structures in the restoration plan if terrestrial wildlife habitat is the objective. This objective can be translated into a plan by combining trees, shrubs, groundcovers, grasses and forbs to provide a variety of wildlife foods, dens, roosts and nesting sites (Davis, 1994).

Based on the limited research regarding the necessary width of riparian zones for individual wildlife species, specific recommendations for riparian restoration efforts can not be made, however, it appears that in general bigger is better. In the coastal plains of eastern Texas and Iowa, breeding bird diversity was higher in wider streamside zones than narrow ones (Dickson and Warren, 1993). While Stauffer and Best (1980) found some breeding birds in narrow habitat zones of less than 20 meters; Rudolph and Dickson (1990) show widths of at least 30 meters would be appropriate for amphibians and reptiles. In the Piedmont of Virginia, Tassone (1981) recommended a streamside zone of 60 meters to accommodate neotropical migratory birds.

STREAMBANK STABILIZATION

Streambank erosion is one of the most critical erosion factors related to water quality. As streambanks erode, sediment is washed downstream, eventually choking areas with sediment and diminishing the quality of aquatic habitat. The clearing of native vegetation for cropland, trampling of streambanks by cattle, and the channelization of streams that occur in agricultural lands contribute to higher volumes and velocities of water which can severely erode streambanks. Land use management practices that can reduce the chances of bank failure include (Keown, 1983):

1. Protection of existing vegetation along streambanks - This can include fencing, restrictions on harvesting riparian trees, and removing those trees that are likely to fall into the stream.

2. Controlling irrigation near streambanks - Saturated banks may lead to bank failure because of swelling clay soils and increased groundwater pressure.

3. Control of surface runoff - Standard conservation practices such as contour farming, terracing, and strip cropping can help to control local runoff.

Streambank stabilization refers to a bank's resistance to change and is a function of soil composition and the type, amount, and vigor of vegetative cover. Streambank stabilization techniques work when they retard water flow and promote sediment deposition, and when they provide a protective cover against erosion. Bohn (1986) suggests that rather than absolute immobility, bank stability also can refer to the functional properties of the bank, such as its ability to develop overhang, a status which provides cover habitat for fish.

Vegetative, structural, and in stream approaches to bank stabilization, both singularly and in combination, have been widely applied to small streams. These methods include: (1) vegetation, (2) bed scour control, (3) bank shaping, (4) surface soil stabilizers, (5) tree revetments, (6) log structures, and (7) rock riprap. For the purposes of this report, only vegetative methods of bank stability will be reviewed.

Vegetative Approaches

Vegetation protects and stabilizes streambanks in several ways. Living root systems increase bank stability by mechanically reinforcing soil and reducing the weight of soil overburden through evapotranspiration of subsurface water. The vertical structure of the above ground vegetation provides resistance to streamflow, causing the flow to lose energy and deposit sediment. Some vegetation, such as grasses, sedges, and rushes, lays down under high flows and forms a blanket of protection over the banks. Surface cover absorbs the impact of falling raindrops and reduces the velocity of surface runoff.

For bank stabilization, vegetation is generally divided into two broad categories - grasses and woody plants (trees and shrubs). Vegetation used for stabilization work should be selected on the basis of strength, resiliency, vigor, rapid initial growth, compatibility with the bank slope, ability to withstand periodic inundation, and the ability of the soil at the site to store water for plant growth during dry periods.

Streambank protection requires a combination of both woody and fibrous rooted species. Woody roots provide a structural matrix that reinforces the soil, while the fibrous root systems of grasses , sedges, and forbs bind the finer soil particles together. The roots of woody species usually have a deeper rooting depth and larger roots than herbaceous plants. On very high banks, however, tree root systems may not penetrate to the toe of the bank, If the toe becomes eroded, the weight of the tree and its root mass may cause bank failure.

Willows are a popular bank stabilization tree (Frazee and Roseboom, 1994; Missouri Department of Conservation, 1991). Willows are able to withstand flooding, to stabilize soils, and to grow quickly in saturated areas. A technique called the "willow post method" uses cuttings of native willow posts with cut cedar trees wired to the lower row of willow posts at the stream's edge to act as revetments that reduce the erosive force of the flowing water (Frazee and Roseboom, 1994). Disturbed soil on streambanks are then seeded with native prairie grasses, perennial grasses and legumes. Willow plantings include dormant willow cuttings (1/2 to 1 inch diameter), stakes (1 to 3 inches diameter) and posts (3 to 6 inches diameter). Willow species used in bank stabilization projects in the mid-west have included black willow (Salix nigra), sandbar willow(S. interior), meadow willow (S. petiolaris), heartleaf willow (S. rigida), and Ward willow (S. caroliniana). Black Locust (Robinia peudoacacia L.) has also been used for bank stabilization in western Oklahoma, especially because they can spread by root sprouts (Little, 1985). Other species used for erosion control are listed in Table 1.

For the grasses, tall grass prairie species are more effective than short cool-season grasses at providing bank stability because of their deeper fibrous root system (Schultz et al., 1991). There can be up to nine times more roots in the top 45 cm of soil and up to five times more at 100 cm depth for prairie grass species than for cool-season species. Platts et al. (1987) list many species of sedges and rushes that are excellent for bank stabilization.

Logan et al. (1979) developed vegetation guidelines based on duration of inundation for choosing the appropriate vegetation for streambank projects. The first task is to define the duration and recurrence interval of various levels (stages) of flow. These are the normal water mark, high water mark, and flood level. Then, the streambank is divided into four zones (toe, splash, bank and terrace) based upon the normal, high, and flood water elevation expected for the stream. Finally, native plants are selected for each zone based on their adaptability to inundation

by streamflow. Plants used in the splash zone need rhizomes that can generate top growth rapidly following loss by stream erosion. They must be adaptable to long periods of inundation. Plant species used in the bank zone can be less flood tolerant. The terrace zone should be seeded first with grasses and legumes to provide quick vegetative cover. A natural community of shrubs and trees can be established later. Communities rather than monocultures should be planted, with natural selection determining which species are most adapted to the specific site. Table 2 lists the habitat requirements for selected grasses, shrubs, and trees that are used for riparian restoration in the Great Plains ecoregion of Oklahoma.

Table 2. Soil moisture and shade tolerance characteristics of select grasses, shrubs and trees for riparian restoration in central and western Oklahoma (only plants with readily available seed sources included). Information is from W.E. Fjeseth, District Conservationist, Mangum, Oklahoma Field Office, NRCS.

Saturated Soil to Top of Bank

Species		Shade Tolerance	Comments
Arroyo Willow	Salix lasiolepis	full sun	plant cuttings
Coyote Willow	S. exiqua	sun to shade	plant cuttings
Pussy Willow	S. discolor	sun to shade	plant cuttings
Sandbar Willow	S. interior	full sun	plant cuttings
Gooding Willow	S. goodingii	full sun	plant cuttings
Scouler's Willow	S. scouleriana	full sun	plant cuttings
Purpleosier Willow	S. purpurea	sun to partial shade	plant cuttings
Common Reedgrass	Phragmites communis	sun to partial shade	waterline to 1' below
Eastern Gamagrass	Tripsacum dactyloides	sun to partial shade	top of bank
Western Wheatgrass	Agropyron smithii	full sun	—
Kanlow Switchgrass	—	sun to partial shade	waterline to 10' above

Top of Bank — Damp and Drier Habitat

Species		Shade Tolerance	Comments
Red Raspberry	Rubusidaeus ssp. strigosus	sun to shade	—
Wood's Rose	Rosa woodii	sun to shade	—
Eastern Cottonwood	Populus deltoides	full sun	—
Common Privet	Ligustrum vulgare	sun to shade	use stems like willows
Red-osier Dogwood	Cornus sericea ssp. sericea	sun to partial shade	—
Gray Dogwood	C. racemose	sun to shade	use stems like willows
Flowering Dogwood	C. florida	sun to shade	—
Roughleaf Dogwood	C. drummondii	sun to partial shade	—
Silky Dogwood	C. amomum	sun to partial shade	—
Redbud	Cercis canadensis	sun to shade	plant stems like willows
Buttonbrush	Cephalanthus occidentalis	sun to shade	—
River Birch	Betula nigra	sun to shade	—
Mondo Grass	Ophiopogon japonicus	sun to shade	—
Creeping Lily Turf	Lirope Spicata	sun to shade	—
Giant cane	Arundinara gigantea	sun to shade	—
Giant reed	Arundo donax	—	—

In-Channel Modifications

While there is no argument that structural modifications should be made where they are needed, there is debate concerning when these changes should be made during a restoration project (Elmore and Beschta, 1989). The use of structures too early in a project, it is argued, "locks" the stream into a fixed location and condition that cannot be sustained. Instead, the restoration process first should address watershed runoff and sedimentation issues, and revegetation of the riparian area and streambanks. Only after several years of vegetation recovery should the type and location of structures be considered.

Experience has shown that a relatively few simple types of structures - deflectors, dams, and shelters - provide all that is necessary for stream habitat reclamation (Duff, 1992).

Deflectors

Current deflectors are used to create scour pools, remove silt from spawning gravels, and protect banks from erosion. Deflectors are usually anchored to a streambank and angled at approximately 45° from the current. They extend about halfway into the channel. They can be constructed from logs, rocks, or boulders.

The most critical step in installation is identifying the proper site. The following list of location criteria were reported by Wesche (1985).

- Typical placement is in wider, shallow, lower gradient stream sections lacking pools and cover (Seehorn, 1992).
- Locations where the gradient exceeds 3% should be avoided (U.S. Forest Service, 1969).
- Either avoid reaches having vast flow fluctuations or design low-profile structures geared for the low-flow channel (U.S. Forest Service, 1969; Cooper and Wesche, 1976).
- Don't build at the head of riffles as this may cause damming of the stream (White and Brynildson, 1967; Nelson et al., 1978).
- Avoid reaches that carry a great deal of debris as this may result in clogging or damming (Claire, 1980).
- The bank opposite the deflector must be stable (Claire, 1980).
- Avoid areas having a soft and/or unstable substrate (Barton and Winger, 1973).

- In straight reaches, alternating deflectors spaced 5-7 channel widths apart can produce a natural sinuous pattern of flow (Nelson et al., 1978; Lere, 1982).

- Avoid steep, high, eroded banks unless the plan calls for stabilizing the entire height of the bank (Seehorn, 1992).

- Be certain that bank conditions are such that it will be possible to anchor the ends of the structure 1.2-1.8m into the bank (Seehorn, 1992).

- Point bars can provide an opportunity for constructing low-profile gabion or rock deflectors that consolidate and direct flow to the opposite stable bank (Cooper and Wesche, 1976).

Dams

Low-profile dams have been constructed of boulders, logs, and gabions of various design. They are commonly used to deepen or create new pools, and act as a trap for organic material used as food by stream invertebrates. Wesche's (1985) review lists some critical location criteria:

- Generally, low dams are successful on smaller (1-9m wide), high-gradient (0.5-20% slope) headwater streams not susceptible to excessive flood flows (peaks from approximately 2.8 to 5.7 m^3/sec) (Raleigh and Duff, 1980; White and Brynildson, 1967).

- A good location for placement is in a straight, narrow reach at the lower end of a steep break in the gradient (Seehorn, 1992).

- The stream bed substrate should be stable.

- The banks should be stable and well defined.

- It should be possible to anchor both ends of the dam well into the banks (1-2m).

- Successive structures should be placed no closer than 5-7 channel widths apart (White and Brynildson, 1967).

- The reach selected should be pool-deficient.

- A site should be selected which allows low dam height (0.3m) to be maintained to allow fish passage but still enhance pools (Alvarado, 1978).

Shelters

Undercut banks, debris jams, and overhanging vegetation provide valuable streamside habitat. Log overhangs, trees, rootwads, and boulders are used to provide bank cover (Seehorn, 1992). They often double as bank stabilizers. Cover logs and rootwads are best used at stream meanders or in combination with deflectors. Boulders can be used in most stream situations but locating near streambanks should be done with caution to avoid erosion.

GRAZING MANAGEMENT STRATEGIES

Impacts of Livestock

Higher forage volume, quality and variety, distance to water and shade are cited as reasons livestock favor riparian habitat as compared to adjacent upland areas (Kauffman and Keueger, 1984; Chaney et al., 1990). Platts and Raleigh (1984) summarized the direct effects of livestock grazing:

1. Higher stream temperatures from lack of sufficient woody streamside cover.
2. Excessive sediment in the channel from bank and upland erosion.
3. High coliform bacteria counts from direct entry and upper watershed sources.
4. Channel widening from hoof-caused bank collapse and later erosion by water.
5. Change in the form of the water column and channel it flows in.
6. Change, reduction, or elimination of vegetation.
7. Elimination of riparian areas by channel degradation and lowering of the water table.
8. Gradual stream channel trenching or braiding.

Skovlen (1984) suggested that vegetation recovery after release from excessive grazing generally takes 5 to 15 years. However, little is known about the recovery time for channel and streambank morphology, and water flow regimens. Channel and bank recovery processes may involve considerable sediment loss before recovery and stabilization occurs.

Considerations for Livestock Riparian Management

In general, the methods for controlling cattle during riparian zone rehabilitation include:

1. exclusion of livestock grazing with stream corridor fencing.
2. managing riparian areas as separate "special use pastures" to get tight control over the season, duration, and intensity of livestock use.
3. using some alternative and grazing strategy to limit the season, duration, and intensity of livestock use (Clary and Webster, 1989).

Researchers have often used exclosures to eliminate grazing along stream reaches. Platts and Rinne (1985), in an extensive literature review, showed that riparian habitats benefited greatly after being fenced to eliminate heavy livestock grazing. Some commonly used grazing strategies include deferred, rest-rotation, and season-long grazing. After exclosures, rest-rotation grazing schemes and special use pastures have been the most successful in the maintenance of riparian ecosystems. Platts (1982) found that when rest-rotation strategies call for livestock to utilize riparian vegetation at a rate of 65% or more (percentage of weight removed), riparian habitat alteration occurs. In contrast, Platts found that riparian alteration may be insignificant when utilization is less than 25 percent. In addition to percent removal, residual herbaceous plant height at the end of the growing/grazing season must be considered. Elmore (1988) suggested that 3 to 4 inches of stubble height would maintain plant vigor, provide stream bank protection, and aid deposition of sediments. Clary (1987) developed a relationship between percentage utilization and stubble height of riparian grasses. He found that between 40 to 50% utilization and maintenance of 3 to 4 inches of residual stubble height would maintain plant-vigor and riparian ecosystem functions.

Managing season of use by livestock is another important tool to consider when livestock's use of the riparian area must be limited to ensure ecosystem function. Spring or summer grazing may be preferred to fall or winter in many situations to maintain proper streambank structure and function Elmore and Beschta, 1989). A fall-grazed plant community, it is argued, has a reduced ability to protect existing banks and to trap new sediments. Reviews by

Meehan and Platts (1978) and Platts (1981) showed that no grazing system is completely capable of maintaining high levels of forage use while rehabilitating damaged streams and riparian zones.

Once it has been determined that livestock grazing should continue, management practices should:

1. limit grazing intensity and season of use to provide sufficient rest to maintain plant vigor.

2. ensure sufficient vegetation to protect streambanks and trap sediments during periods of high flows, and,

3. control the timing of use to prevent damage to streambanks when they are most vulnerable to trampling (Marlow et al., 1987).

PLANNING THE RESTORATION PROJECT

Patrick (1973) states: "Man must remember that the streams and the flood plains have evolved over long periods of time, and have developed a system that is best for the natural conditions at hand. He should study it carefully and make sure that modification follows the dictums of nature."

A good first step in the planning process should be to form an interdisciplinary team to determine how best to reclaim or enhance a riparian area. This team may include a fisheries biologist, vegetation specialist, water quality specialist, hydrologist, hydraulics engineer, and soil scientist. As a second step, each member should develop a list of questions which need to be answered regarding their specialty and its relationship to the project at hand (Wesche, 1985).

There are many references that detail the methods available to answer the questions raised by each specialist. Heede (1979) demonstrated how hydrologists can predict impacts of stream restoration projects when field time and on-site data are limited. Aquatic fauna and habitat evaluation methodologies include the Habitat Quality Index of the Wyoming Game and Fish Department (Binns, 1979) the Physical Habitat Simulation (PHABISM) System models developed by the USFWS Instream Flow Group (Milhous et al., 1981), the Index of Biological Integrity (IBI) (Karr et al., 1986), and the Rapid Bioassessment Protocols (Plafkin et al., 1989).

The stability of stream channels and banks substantially affects the quality of riparian and aquatic habitats. The U.S. Forest Service had developed the Pfankuch (1978) Stream Stability Rating (SSR) to rate channel and bank stability. The SSR is used by over 60% of all national forests for cumulative impact analysis (Parrott et al., 1989).

Stream classification can be used as a tool for comparing reaches along a stream or within a watershed or other management unit. Rosgen (1985) introduced a stream classification method based on channel and floodplain morphology. It is unique among many classification methods in that it addresses the physical attributes of the stream. In contrast, many methodologies have been developed to classify riparian vegetation (Platts et al., 1987; Kovalchick, 1987). Kovalchick's publication also includes discussions on management and rehabilitation.

Platts et al. (1987) set out six basic steps for the collection or riparian habitat information (Figure 1), the goal being to avoid collecting inadequate, improper, or excessive information. Such an inventory is needed for subsequent resource planning and management processes.

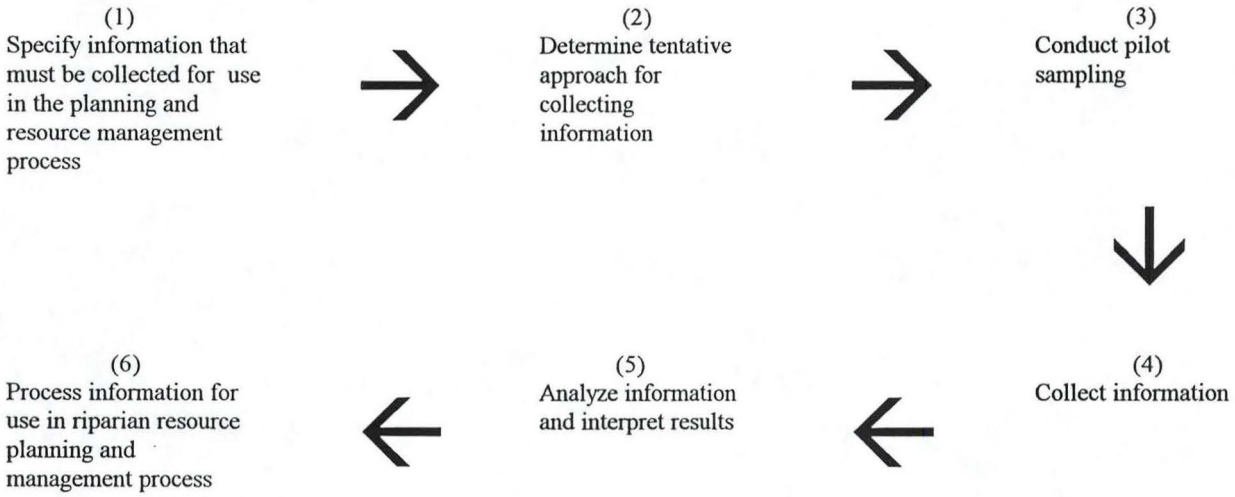
(1)
Specify information that must be collected for use in the planning and resource management process
(2)
Determine tentative approach for collecting information
(3)
Conduct pilot sampling
(4)
Collect information
(5)
Analyze information and interpret results
(6)
Process information for use in riparian resource planning and management process

Figure 1—Steps for a field sampling program to obtain useful information for riparian resource planning and management processes.

After finalization and implementation of the restoration plan, the final phase of the planning process is the monitoring and evaluation of the project. This phase is overlooked in most restoration projects (Wydoski and Duff, 1982).

The monitoring study should identify specific goals – for example, that the riparian buffer will trap soil that is eroding from the row-cropped upland, or the target (mean and confidence interval) abundance of a riparian bird – desired after a specific period of time. These goals can be used to develop null hypotheses that will guide the sample design and statistical analyses used to evaluate the projects success. Hypothesis testing ensures that the manager can "be confident that his or her conclusions have a sound basis and, further, that management decisions arising from these conclusions are supportable to the public" (Morrison, 1994).

Platts et al. (1987) laid out the steps (Figure 2) that must be followed to obtain meaningful results from a monitoring study.

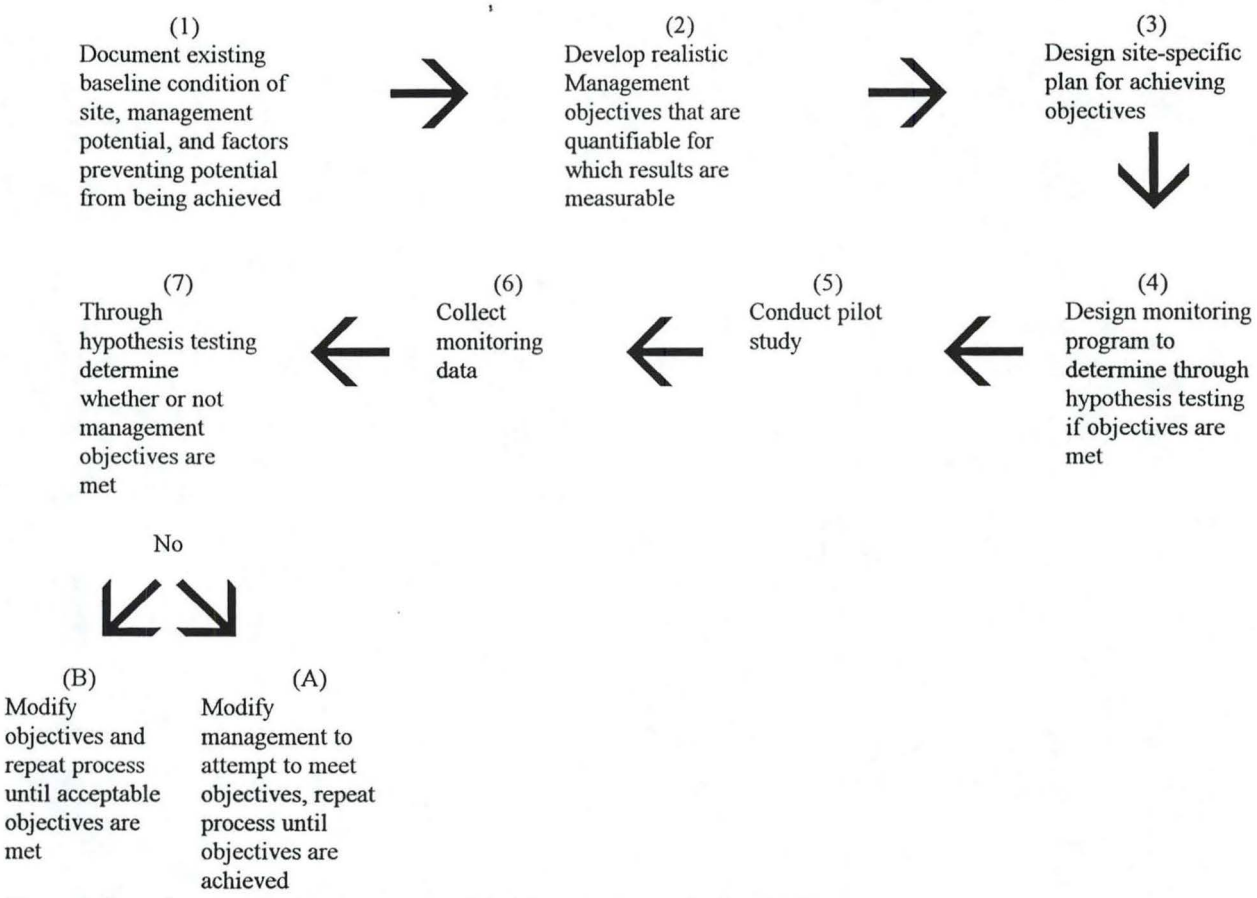
(1)
Document existing baseline condition of site, management potential, and factors preventing potential from being achieved
(2)
Develop realistic Management objectives that are quantifiable for which results are measurable
(3)
Design site-specific plan for achieving objectives
(4)
Design monitoring program to determine through hypothesis testing if objectives are met
(5)
Conduct pilot study
(6)
Collect monitoring data
(7)
Through hypothesis testing determine whether or not management objectives are met
No
(A)
Modify management to attempt to meet objectives, repeat process until objectives are achieved
(B)
Modify objectives and repeat process until acceptable objectives are met

Figure 2–Steps for a monitoring program (modified from Armour and others 1983).

This literature review discusses the framework for approaching riparian zone restoration; provides an overview of restoration techniques that could be applicable in Oklahoma; and describes methods to assess the success of restoration techniques. Also attached is a draft set of recommendations for establishment of riparian buffers, an output of a joint effort by the Oklahoma State University Cooperative Extension Service and the Oklahoma Conservation Commission funded through an EPA project entitled "Management Program for Riparian Areas to Protect Water Quality."

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Riparian Buffer Recommendations

Technical Staff
March, 1996

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I. EXECUTIVE SUMMARY

This report is one of the designated outputs of the EPA-funded project entitled the "Management Program for Riparian Areas to Protect Water Quality," conducted jointly by the Oklahoma State University Cooperative Extension Service and the Oklahoma Conservation Commission. This document has been prepared by the Technical Staff component of this project and reviewed by a Technical Review Group. The Technical Staff is made up of individuals from Oklahoma State University and the Natural Resources Conservation Service. The Technical Review Group represents various state and federal environmental agencies including: the Oklahoma Department of Environmental Quality, Oklahoma Water Resources Board, Oklahoma Department of Wildlife, Oklahoma Department of Agriculture, Office of Secretary of the Environment, Natural Resources Conservation Service, and the U.S. Forest Service. An Advisory Committee composed of representatives of commodity and interest groups is also a constituent of this project.

Riparian areas are an ever-diminishing natural resource that warrant special consideration. These areas can be important factors in mitigating or controlling the effects of nonpoint source pollution and are vital elements of both the terrestrial and aquatic ecosystems. The benefits afforded by riparian areas are both varied and numerous. Clearly, riparian areas should be managed, protected, and restored. The goals of this project attempt to address aspects of this need, by among other things, developing policy for riparian area management, and establishing technical guidelines for riparian protection measures.

One of the first steps in this project was to reach a consensus among the participating state and federal agencies on riparian area definition. After reviewing numerous riparian area definitions, the Technical Review Group established a working definition:

> Riparian areas are defined as geographically delineated areas with distinct resource values that occur adjacent to streams, lakes, ponds, wetlands, and other specified water bodies. As a guide, stream channels are identified by dotted or solid blue lines on the U.S. Geological Survey 7 1/2 minute quadrangle map.

This document reviews riparian buffer specifications compiled by the Technical staff from state and federal agency sources, and contains a proposed framework for riparian buffer design. A three-zone riparian buffer concept has been selected as the prototype for a complete, engineered riparian buffer system and is detailed in this report. The three zone riparian buffer system consists of an undisturbed zone directly adjacent to the water body, designated as Zone 1; a managed transition zone, Zone 2; and an area designed for runoff or sediment control, Zone 3. Each zone has associated management activities and suggested minimum design widths. Riparian buffer width specifications are an important factor in buffer design; therefore, width recommendations from several sources were reviewed for this report.

II. RECOMMENDATIONS

1. Definition for general guidelines: Riparian areas are defined as geographically delineated areas with distinct resource values that occur adjacent to perennial or intermittent streams, lakes, ponds, wetlands, or other specified water bodies. Stream channels are identified for purposes of these guidelines by dotted or solid blue lines on the U.S. Geological Survey 7 1/2 minute quadrangle map.
2. Riparian areas should be managed, protected, or restored to enhance surface water quality, ground water quality, and aquatic ecosystem health where feasible.
3. Riparian buffers should consist of one to three distinct zones. The three-zone riparian buffer system is recommended where conditions allow. Its use should achieve maximal benefits and provide a smooth transition from upland uses. Other buffer arrangements can also provide benefits. To perform effectively, riparian buffers should be designed to disperse flow and promote infiltration, to spread out or distribute concentrated flow, and to remove materials from surface runoff and shallow subsurface flow. The zone directly adjacent to the water body is designated as Zone 1. Zone 1 is an undisturbed area of native trees, shrubs, or grasses with a recommended minimum horizontal width of 15 feet. An area equivalent to Zone 1 is always recommended regardless of buffer arrangement. Zone 2 is a managed zone of native trees, shrubs, or grasses with a minimum recommended width of 60 feet. Periodic timber or forage harvest is encouraged in Zone 2. Zone 3 is designed as a runoff control zone of dense, perennial grasses and forbs with a minimum width of 20 feet recommended. Livestock grazing can be an important management option in Zone 3.
4. Riparian buffers will be effective only when used in conjunction with sound upland erosion control and nutrient management. Use of this practice without these measures can cause damage to buffer vegetation and increase rill and gully formation causing dramatic reduction in buffer efficiency. Poor upland management will result in high maintenance costs.
5. Riparian buffers should be considered where: 1) water quality is impaired and adjacent land use contributes to degradation, 2) wildlife habitat enhancement is desired, 3) good water quality exists and protection against future impairment is desired, 4) streambank erosion is a concern, or 5) stream temperature and aquatic habitat are considerations.

III. INTRODUCTION

Historically there has been little attention focused on the management of riparian areas in Oklahoma. However, two reports produced in the 1980's by the U.S. Fish and Wildlife Service and the Oklahoma Department of Wildlife, entitled *Bottomland Hardwoods of Eastern Oklahoma* (1985) and *Riparian Areas of Western Oklahoma* (1987), helped call to attention the vital role of these transitional areas between the aquatic and terrestrial ecosystems. These reports clearly document the alarming rate of riparian area destruction and the need for protection measures in Oklahoma.

Our conception of water quality protection has evolved along with the understanding of benefits of riparian areas. Water quality protection has changed from a myopic view focused on chemical and sediment concentrations to a more holistic view of stream health management. Such a view considers both aquatic and terrestrial habitat parameters as fundamental elements. Riparian areas are principal components of both ecosystems. They provide food and habitat for stream communities, and when used in conjunction with sound upland management, can be important in mitigating or controlling the effects of nonpoint source pollution.

With this in mind, Oklahoma State University Cooperative Extension Service (OSU) and the Oklahoma Conservation Commission (OCC) are conducting a joint EPA-funded project entitled "Management Program for Riparian Areas to Protect Water Quality." The project has three levels of activity: a Technical Staff, Technical Review Group, and Advisory Committee. The Technical Staff is composed of participants from OSU and the Natural Resources Conservation Service. The Technical Review Group consists of representatives of state and federal environmental agencies including: the Oklahoma Department of Environmental Quality, Oklahoma Water Resources Board, Oklahoma Department of Wildlife, Oklahoma Department of Agriculture, Office of Secretary of the Environment, Natural Resources Conservation Service, and the U.S. Forest Service. Commodity and interest groups are represented in the Advisory Committee.

One of the primary outputs identified in this project is a handbook of riparian management guidelines. This document is an interim report on riparian management practices and a proposed protection scheme that will be included in the handbook. In compiling this report, the Technical Staff contacted forty-nine states in an effort to obtain information on riparian management. Two states reported that they had nothing in writing, and an additional three states indicated that they are currently working on materials for their riparian areas. Twenty-eight states provided information.

This report incorporates information from several state and federal governmental agencies. The proposed riparian buffer scheme is based largely on the work of David J. Welsch with the U.S. Forest Service and the riparian forest buffer standards of the Natural Resource Conservation Service (NRCS). It is intended as guidance for conservation district officials who will be assisting landowners in riparian area protection measures.

The "Findings" section presents results from the Technical Staff's review of literature and the materials obtained from the state and federal agencies. Draft specifications for the riparian buffer system are located in the final segment of this report along with the specifications in tabular format.

IV. FINDINGS

Material from several state and federal governmental agencies was reviewed in the process of developing the proposed riparian buffer zone concept for Oklahoma. Width requirements are a critical factor in buffer design; therefore, width information from several sources were compared in this section. There are two major types of width requirements: fixed minimum width and variable width. Fixed minimum width requirements, as the name implies, start with a fixed minimum width buffer and, if necessary, extend it based on site-specific conditions. These fixed-width buffers have the advantages of relatively simple implementation and administration. Variable width requirements allow width determination based entirely on site-specific conditions. Variable width buffers allow greater sensitivity to site-specific protection needs (Belt *et al.* 1992). Regardless of the system employed, slope, roughness, erodibility and stream water use appear to be the critical factors in determining buffer width (Belt *et al.*, 1992; Phillips, 1989 a and b; Welsch, 1991).

Other important considerations in riparian buffer design include the amount of allowed vegetative removal in the riparian zone and the selection of riparian zone width requirements based on several design functions such as N removal, sediment trapping, or stream shading (Belt *et al.*, 1992).

State and Agency Width Requirements

Idaho (Belt *et al.*, 1992)

- Width requirements vary according to stream class. Widths are measured along the slope distance starting at the ordinary high water mark, and represent total widths.
- Class I streams (drinking water or important for fish habitat): 75 ft. minimum width.
- Class II streams (headwater streams without a significant fishery): 5 ft. minimum width

Washington (Belt *et al.*, 1992; Washington, 1993)

Riparian zone width requirements are designated differently for eastern and western Washington for varying ecological needs.

- Western Washington: widths measured horizontally from high-water mark by map projection.
- 25 ft. min - 100 ft. max - determined by stream class and stream width.
- Eastern Washington: width measured horizontally from the ordinary high-water mark to the point of vegetative change from wetland to upland.
- 30 ft. min - 50 ft. max - for partial cut timber harvesting in adjacent upland area.
- 30 ft. min - 300 ft. max - for other than partial timber harvesting in adjacent upland area.

California (Belt *et al.*, 1992)

In California, riparian zone width requirements are determined by watercourse class (determined by water supply and fishery use) and by adjacent land slope.

- Class I Watercourse (depending on 4 slope classes): 50 ft. min - 200 ft. max
- Class II Watercourse (depending on slope class): 50 ft. min - 150 ft. max
- Class III and IV Watercourses: requires field determination.

Oregon (Belt *et al.*, 1992)

Width requirements are determined by stream class defined on basis of predominant water use (water supply, fishery, recreation).

- Class I streams (set at 3 times average stream width at high flow): 25 ft. min - 100 ft. max
- Requirements for other stream classes are not given.

Montana (Montana, 1991)

- 50 ft. minimum - extends beyond minimum: 1) when steep land borders the stream, 2) when erodible soils border the stream, and 3) to include wetland areas along the stream bottom.

South Carolina (South Carolina Forestry Commission)

Riparian zone buffers are divided into two zones*. These zones differ with respect to practices permitted in each zone. The width of each zone is determined by the % slope from stream bank to 100 ft. perpendicular to the stream.

< 5% slope	5-20% slope	> 20% slope
Zone 1 - 40 ft. Zone 2 - 0 ft.	Zone 1 - 40 ft. Zone 2 - 40 ft.	Zone 1 - 80 ft. Zone 2 - 80 ft.

*Zones 1 and 2 are referred to in this document as the 1^0 and 2^0 zones, respectively.

USDA-FS Northeastern Area (Welsch, 1991)

Width requirements are established for a three-zone riparian zone buffer. Distances are measured horizontally on a line perpendicular to the streambank.

- **Zone 1:** 15 ft. beginning at the streambank top (native forest)
- **Zone 2:** 60 ft. minimum (managed forest)
- **Zone 3:** 20 ft. minimum (grasses and forbs) can be increased to accommodate mowing and land shaping machinery.

The minimum width of buffer areas can also be fixed using several methods.

- **Soil hydrologic groups:** the width of Zone 2 should be increased to include frequently flooded C and D groups. If A and B groups border the watercourse, the minimum widths of Zones 1 and 2 should be adequate.
- **Area:** the buffer should occupy 1/3 of the source area.
- **Soil Capability Class of the buffer strip:** the width of Zone 2 should be increased to provide a combined width of Zone 1 and 2 as follows:

Soil Capability Class	Total Zone 1 and 2 Width
I, II e/s, V	75 ft.
III e/s, IV e/s	100 ft.
VI e/s, VII e/s	150 ft.

Kansas and Connecticut WP7 (Welsch, 1991 modifications)

- **Zone 1:** 15 ft. beginning at the streambank top (native forest; in regions receiving < 20 inches of annual rain, the predominant vegetation may be grasses and shrubs*)
- **Zone 2:** 60 ft. minimum (managed forest; in regions receiving < 20 inches of annual rain, the predominant vegetation may be grasses and shrubs*) can be increased depending on the soil capability class of the buffer area
- **Zone 3:** 20 ft. minimum (grasses and forbs) can be increased to accommodate mowing and land shaping machinery.

* This is an attempt to insure that native vegetation be used in areas where the native riparian zone was/is composed of grasses and shrubs.

NRCS South National Technical Center Interim Standard (USDA-SCS a) and SCS Northeast National Technical Center Interim Standard (USDA-SCS b)

These standards are also modified from Welsch (1991).

- **Zone 1:** 15 ft. beginning within 2 ft. of the normal waterline (native forest)
- **Zone 2:** 60 ft. minimum (managed forest) should be increased to 100 ft. for high sediment or nutrient producing areas.
- **Zone 3:** 20 ft. minimum (grasses and forbs) can be increased to accommodate mowing and land shaping machinery.

Iowa State Agroforestry Research Team Recommendations (IStART, 1994)

IStART also divides riparian zone width considerations into three zones with distinct vegetation. Width variations depend on buffer function and slope and use of the adjacent land. The basic recommendation is:

- **Zone 1:** 30 ft. (trees)
- **Zone 2:** 12 ft. (shrubs)
- **Zone 3:** 24 ft. (native, warm-season grasses)

Non-standard, on-site conditions recommendations: (Widths suggested are total widths).

- **Urban settings:** 50 ft. minimum
- **Higher slopes, lower permeability, or higher intensity land use:** increased widths are required.

Major function recommendations: (Widths suggested are total widths)

- **Sediment removal:** 50 ft. on 0 - 5% slopes. Wider buffers are necessary for steeper slopes.
- **N removal:** 66 ft. - 100 ft.
- **Wildlife habitat:** 100 - 130 ft.

Phillips' Riparian Buffer Delineation Equation (Phillips 1989 a, b)

Riparian zone buffer widths are calculated by comparison with a reference buffer designed for 90% N removal. The reference buffer was considered effective under the "pessimistic" conditions of high runoff volume and a low N removal rate constant.

The buffer delineation equation includes the products of the ratios of Manning's roughness coefficient, buffer width, saturated vertical hydraulic conductivity, slope, and soil moisture storage capacity for a buffer to the reference buffer.

Xiang (1993) used the Phillips' Riparian Buffer Delineation Equation and GIS technology with soil and topographic data base inputs to determine acceptable riparian zone buffer widths over a large continuous area.

Trimble and Sartz (Trimble and Sartz, 1957)

Trimble and Sartz developed an acceptable forested buffer width to allow an acceptable amount of sediment from a sandy loam soil to reach a stream from a nearby logging road. The width, starting with 25 ft. minimum, is based on slope percent.

$$\text{width (ft)} = 25 + (2 * \% \text{ slope})$$

In order to protect municipal water supply watersheds from sedimentation, a more stringent recommendation was made. This guideline was adopted by the USDA-SCS for forested riparian zone buffers in municipal watersheds and critical areas (USDA-SCS, 1988).

$$\text{width (ft)} = 50 + (4 * \% \text{ slope})$$

Nieswand *et al.* (1990) recommendations for New Jersey

Distances are measured from bankfull elevation of streams and normal pool elevation for lakes and exclude distances with > 15% slope and strips of impervious surfaces. Assumes a ground cover condition of forest with heavy litter and hay meadow. The appropriate width is the largest of 50 ft. buffer or a buffer width required to produce a arbitrary travel time (assumed to produce a significant reduction in NPS pollution load) through the buffer.

V. RIPARIAN BUFFER SPECIFICATIONS

For an overview of riparian buffer specifications, refer to the riparian buffer matrix beginning on page 15. Also see Figure 1.0, "Cross sectional view of the three-zone riparian buffer matrix," on page 13.

Scope: These specifications, modified for Oklahoma from Welsch (1991), establish guidelines for areas to be managed as riparian buffers.

Definition: Riparian areas are defined as geographically delineated areas with distinct resource values that occur adjacent to perennial or intermittent stream channels, lakes, ponds, or wetlands[1]. Stream channels are identified for the purposes of these guidelines by the dotted and solid blue lines on the USGS 7 1/2 minute quadrangle map. Riparian buffers are a riparian areas that are designed or engineered to provide certain water quality functions.

Purpose: The purpose of riparian buffers is to protect and enhance surface and ground water quality and aquatic ecosystem health. Riparian buffers accomplish this by removal of nutrients, sediment, organic matter, certain pesticides, and other pollutants from surface runoff and shallow subsurface flow[2] from upland sources prior to entry into surface water and ground water recharge areas by deposition, absorption, adsorption, plant uptake, and denitrification.

Riparian buffers also reduce flood heights and flood velocities, stabilize stream banks and lake shores, and provide important wildlife habitat. Forested riparian buffers shade streams thus improving aquatic habitat and support productive forests which can be harvested periodically. Grassed buffers provide productive livestock pasture.

Conditions where practice applies: Riparian buffers are low maintenance stable areas at the water body edge that provide a smooth transition from intensive upland land use. They are intended to form a buffer between cropland, pasture, hayland, forestland, or rangeland and water bodies including: perennial or intermittent streams, lakes, ponds, or wetlands.

Riparian buffers will be effective only when used in conjunction with sound upland management practices for runoff and erosion control and for nutrient and pesticide management. In areas where erosion and sediment yield are high (erosion rate greater than 3-5 tons/acre/year), severe sheet, rill, and gully erosion must be controlled for this practice to function correctly. In areas with concentrated runoff flow conditions, practices to disperse flow and promote infiltration and to impede concentrated flow are necessary for proper function. In areas with high nutrient loads and/or high pesticide rates, a nutrient and/or pesticide management plan is necessary to insure the buffer's nutrient buffering/filtering capacity is not exceeded. Use of this practice without erosion and runoff control and nutrient and pesticide management can cause adverse impacts including: damage to buffer vegetation requiring periodic replanting and an increase in rill and channel development causing dramatic reduction in buffer efficiency. These adverse impacts result in high maintenance costs.

Riparian buffers should be considered where: 1) water quality is impaired and adjacent land use contributes to degradation, 2) wildlife habitat enhancement is desired, 3) good water quality exists and protection against future impairment is desired, 4) streambank erosion is a concern, or 5) stream temperature reduction and improved aquatic habitat is a consideration.

Design Criteria: Where conditions allow, riparian buffers should consist of three distinct zones. An undisturbed zone directly adjacent to the water body is critical for maintenance of proper buffer function and is always recommended. A transition area of one to two zones is recommended in the direction of flow. Specific recommendations in regard to width, purpose, vegetation, management, livestock, forestry, wildlife, and flow for each zone are given in the following section. This information is also presented in tabular format at the end of this document.

The three zone riparian buffer is designed to achieve the maximum benefits expressed in the Purpose section above; however, other buffer arrangements can be expected to achieve some reduced level of benefits. Other acceptable buffer arrangements are: 1) ZONE 1 as a forested zone adjacent to the water body and ZONE 3 as a grassed buffer strip; and 2) ZONE 1 only, as a grassed buffer strip adjacent to the water body. Note that protection of the area directly adjacent to the water body, equivalent to Zone 1, is always recommended

Maintenance Guidelines: Buffers should be inspected annually (and immediately following severe storms) for evidence of buffer erosion or concentrated flow. Prompt corrective action should be taken to stop erosion and restore sheet flow.

The following should be avoided within buffer areas: 1) excessive use of fertilizers, pesticides, and other chemicals, 2) vehicular traffic, and 3) removal or disturbance of vegetation and litter inconsistent with erosion control and buffering objectives. Fertilizers can be used on zones planted to grass only if determined necessary by a soil nutrient test to encourage vigorous growth.

As forested buffers reach 60 years of age, ZONE 1 and ZONE 2 will produce large stable debris, such as logs. This debris creates small dams which trap and hold detritus for processing by aquatic insects thus adding energy to the stream ecosystem, strengthening the food chain, and improving aquatic habitat. Where debris dams must be removed, attempts should be made to retain useful, stable portions which provide storage of detritus. Removed debris should be placed a sufficient distance from the stream so that it will not be redeposited in the stream by high water.

Determining total minimum width of the buffer: In a three zone buffer or other acceptable buffer arrangement, zones must have adequate widths to remove pollutants effectively from surface runoff and shallow subsurface flow to achieve the desired enhancement and protection of aquatic ecosystems and water quality. ZONE 1, 2, and 3 are recommended to have minimum widths of 15, 60, and 20 feet, respectively.

The minimum width of streamside riparian buffer areas can, in addition to the general minimum width requirements, be fixed according to the following criteria based generally on slope and soil permeability. Specific criteria such as buffer and upland slope, buffer soil permeability, buffer hydrologic soil group (HSG), source area, buffer soil capability class, or stream/water body class designation can be used to extend width recommendations above minimum levels. Specific buffer width recommendations have not yet been set for this project.

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[1]Karst formations, other small ground water recharge areas, and certain ephemeral and intermittent streams might also be included but need further discussion. Some wetlands function as nutrient sinks and when they occur in fields or at field margins can be used for renovation of agricultural surface runoff and/or drainage. However, most wetlands associated with open water are subject to periodic flushing of nutrient laden sediments and therefore require riparian buffers to protect water quality.

[2]Defined as flow in saturated conditions near or within the root zone of trees and other woody vegetation at depths where bacteria, oxygen, and soil temperature contribute to denitrification.

Zone 1

Of prime importance for protection, is the region directly adjacent to the water body, defined as Zone 1. An area equivalent to Zone 1, is recommended for all water bodies. Zone 1 should be left undisturbed for proper functioning condition. In some cases where stream channel instability is a problem, reshaping of Zone 1 may be necessary. This however, is not addressed at this time. The purpose of Zone 1 is to create a stable ecosystem along the water's edge and provide soil/water contact to facilitate nutrient buffering processes. This area may also provide shade to lower water temperature, and improve aquatic habitat. If trees are present, detritus and large woody debris may be contributed to the ecosystem.

Width: 15 feet minimum is considered appropriate. All distances are measured horizontally on a line perpendicular to the streambank, beginning at the top of the bank. Note that this may be different from the direction of overland flow, as in a high bank.

Vegetation: Predominant vegetation in Zone 1 consists of a variety of native riparian tree and shrub species suitable to soil and site conditions. This might also include any plantings which are necessary for streambank stabilization during a period of establishment. Plant native streamside species on HSG C and D and native upland species on HSG A and B. In regions receiving less than 20 inches of annual precipitation or where the water table will not support trees, the predominant vegetation may be a mixture of grasses and shrubs. Refer to the State Standard and Specifications for Tree Planting and for Streambank and Shoreline Protection for specific requirements to establish, manage, and maintain trees. Fertilizer and lime, helpful for establishing vegetation, must be used with caution and are not recommended.

General Management: It is critical for proper functioning that Zone 1 be undisturbed to the greatest extent possible. Activities within this zone should be limited to any necessary bank stabilization or removal of trees presenting unusual hazards such as blocking culverts or creating dangerous hydraulic obstructions. Overland equipment is prohibited except at designated stream crossings. Management for wildlife habitat and aesthetics are compatible secondary objectives as long as their management does not jeopardize the primary function of the buffer. If other management objectives are desired, appropriate species adapted to site conditions may be selected. Consult with Natural Resource Conservation Service (NRCS), U.S. Forest Service (USFS), or U.S. Fish and Wildlife Service (USFWS) for species selection.

Livestock Management: Livestock presence is discouraged in this zone except for designed stream crossings (allowed only on small streams) and for designed watering facilities located outside the buffer or within the buffer, if the watering facility is fenced. This recommendation is made because of probable negative impacts such as streambank instability, livestock trails, and vegetative damage; all of which limit buffer effectiveness in this zone. If the decision is made to allow livestock, intensive management is necessary to protect the buffer. This might include controlled, short term grazing when conditions are dry and firm and when vegetation is least vulnerable to damage.

Forestry Management: Logging should be limited to the occasional removal of high value trees where water quality values are not compromised.

Flow Requirements: Flow should be limited to subsurface and shallow, uniform flow in this zone. Concentrated flow must be converted to subsurface or shallow, uniform flow prior to entering Zone 1 because buffering effectiveness would be short-circuited otherwise. Open ditches and subsurface drains crossing Zone 1 are discouraged. Use of techniques such as grading and shaping along with devices such as level lip spreaders can be used to encourage uniform flow. Care should be exercised when employing

these techniques and devices to minimize disturbance. Techniques and devices should be located in the outer buffer zone to limit concentrated flow throughout the buffer.

Zone 2

Zone 2 is the intermediate zone where active management may take place. Its purpose is to provide the necessary contact time and carbon energy source for buffering to occur as well as to provide long-term storage of nutrients in forest trees.

Width: A 60 feet minimum width is recommended, measured horizontally in the direction of overland flow. Minimum width requirement may be increased based on determining the minimum width of the entire buffer. See discussion on pg. 9.

Vegetation: Predominant vegetation in Zone 2 is also composed of a variety of native riparian tree and shrub species suitable to the site, as well as species necessary for soil stabilization during an establishment period. Refer to NRCS, USFS, or USFWS for species selection if other benefits are desired. Plant native streamside species on HSG C and D and native upland species on HSG A and B. Deciduous tree species are important for leaf litter carbon leachate production which drives bacterial processes, and should be considered where possible. Evergreens are important for potential nutrient uptake in winter months. In regions receiving less than 20 inches of annual precipitation or where the water table will not support trees, the predominant vegetation may be a mixture of grasses, forbs, and shrubs. The State Standard and Specifications for Tree Planting and for Streambank and Shoreline Protection should be referred to for specific requirements to establish, manage, and maintain trees.

General Management: Management for wildlife, aesthetics, and timber are compatible with proper buffer functions within Zone 2 as long as leaf litter, detritus, large woody debris production, and shade are maintained, and their management does not impair the primary function of the buffer. Mechanical site preparation which exposes large amounts of bare soil, such as rootraking and windrowing, piling, disking, or bedding is prohibited.

Livestock Management: The same recommendation for Zone 1 applies in Zone 2. However, on areas planted to grass, controlled, intensive grazing is allowed when conditions are dry and firm. Removal of vegetative growth may be accomplished with grazing or hay harvesting, and is preferred to mowing.

Forestry Management: Periodic harvesting and timber stand improvement (TSI) with appropriate recommendations from state and federal forestry agencies are allowed and encouraged to maintain vigorous growth and to remove nutrients and pollutants stored in the timber. All forest harvesting operations shall be in compliance with State Standard and Specifications for Improved Harvesting and with recognized BMP's. Stand density shall be maintained within 25% of forest density guidelines for forest type and size class.

Flow Requirements: The same recommendations for Zone 1 apply for Zone 2.

Zone 3

Zone 3 is designed for runoff control and provides sediment filtering, nutrient uptake, and the space necessary to convert concentrated flow to uniform, shallow sheet flow through the use of techniques such as grading and shaping and devices such as diversions, basins, and level lip spreaders.

Width: A 20 foot minimum width is recommended for this zone, measured horizontally in the direction of overland flow, although additional width may be desired to accommodate land shaping and mowing equipment. Ungrazed grassland may meet Zone 3 requirements.

Vegetation: Dense perennial grasses and forbs to maximize nutrient uptake are recommended for this zone. Vegetation should be maintained in vigorous growth condition, unless this conflicts with wildlife management objectives. Select species adapted to site conditions and with the ability to achieve other benefits such as forage production and wildlife habitat improvement. Refer to Filter Strip Standard for seeding mixtures. Improved grass species are allowed.

General management: Mow and remove clippings to recycle nutrients, promote vigorous sod growth, and control weeds. This zone should be inspected twice annually and may require periodic re-shaping of earthen structures, removal of grading or accumulated sediment, and re-establishment of vegetation. Attention should be given not to mow or harvest during nesting season.

Livestock management: Controlled, intensive grazing, instead of mowing and removal of clipping to remove vegetative growth, and hay harvesting are all allowed when conditions are dry and firm so that earth control structures and vegetation are not damaged. Designed watering facilities should be located outside the buffer; however, a location within the buffer is acceptable if the watering facility is fenced.

Flow requirements: Open ditches and subsurface drains crossing Zone 3 are discouraged; however, drains may outlet water within Zone 3 if the flow is converted to uniform flow upon outlet.

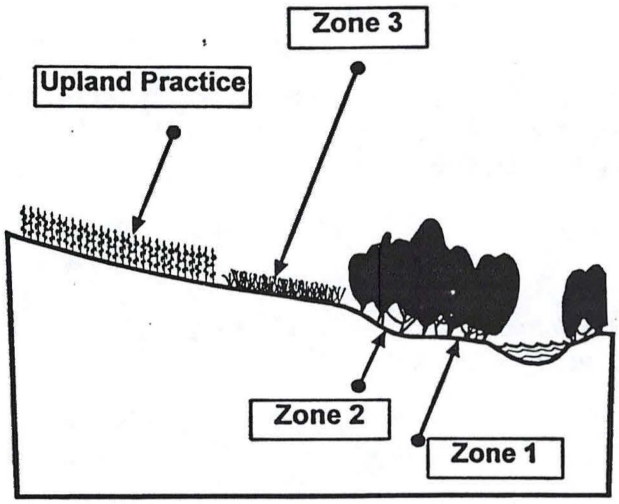

Figure 1.0 Cross-sectional view of the three-zone riparian buffer matrix; (modified from NRCS, Riparian Forest Buffer Standard)

VII. REFERENCES

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VI. APPENDIX

ZONE 1								
WIDTH	PURPOSE	VEGETATION*	GENERAL MANAGEMENT**	LIVESTOCK MANAGEMENT***	FORESTRY MANAGEMENT	WILDLIFE	FLOW REQUIREMENTS****	
15ft minimum width (all distances are measured horizontally on a line perpendicular to the streambank) beginning at the stream bank top	1) Create stable ecosystem adjacent to water's edge 2) provide soil/water contact area to facilitate the nutrient buffering process 3) provide shade to lower water temperature & improve aquatic habitat 4) contribute detritus and LWD to ecosystem	Predominant vegetation composed of variety of native riparian tree and shrub species suitable to soil and site and such plantings necessary for streambank stabilization during establishment period	Bank stabilization and removal of trees presenting unusual hazards such as blocking culverts or creating dangerous hydraulic obstructions. Other overland equipment is prohibited except to cross stream in designed streamcrossings	Livestock presence discouraged except for designed streamcrossings (allowed only on small streams) and for designed watering facilities located outside the buffer or within the buffer (if the watering facility is fenced)	Logging limited to occasional removal of extreme high value trees where water quality values are not compromised		Limited to subsurface and shallow, uniform flow. Concentrated flow must be converted to subsurface or shallow, uniform flow prior to entering ZONE 1. Open ditches and subsurface drains crossing ZONE 1 are discouraged	
* Select species adapted to soil and site and for their ability to achieve other benefits, such as wildlife habitat improvement. Consult with NRCS, FS, or FWS for species selection.								
Native streamside species on HSG C & D and native upland species on HSG A & B.								
In regions receiving less than 20in annual precipitation or where the water table will not support trees, predominant vegetation may be a mixture of grass and shrubs.								
Refer to State Standard and Specifications for Tree Planting and for Streambank and Shoreline Protection for specific requirements to establish, manage, and maintain trees.								
Fertilizer and lime, helpful for establishing vegetation, must be used with caution & are not recommended.								
** Management for wildlife habitat and aesthetics are compatible secondary objectives as long as their management does not jeopardize the primary function of the buffer.								
*** Livestock presence is discouraged because of probable negative impacts such as streambank instability, livestock trails, and vegetative damage; all of which limit buffer effectiveness in this zone.								
Intensive management is necessary to prevent negative impacts if livestock are present in this zone. Lack of management or mismanagement will result in negative impacts.								
Intensive management might include controlled, intensive, short term grazing when conditions are dry and firm and when serious vegetation damage will not occur???								
**** Such concentrated flows are discouraged because they shortcircuit the buffering effectiveness of the buffer.								
Use of techniques such as grading and shaping and devices such as level lip spreaders can be used to encourage uniform flow.								
These techniques and devices should be located in the outer zone to limit concentrated flow throughout the buffer.								

ZONE 2							
WIDTH	PURPOSE	VEGETATION*	GENERAL MANAGEMENT**	LIVESTOCK MANAGEMENT***	FORESTRY MANAGEMENT****	WILDLIFE	FLOW REQUIREMENTS*****
60ft minimum width measured horizontally in the direction of flow (minimum width requirement may be increased based on "Determining total minimum width of the buffer" discussion attached)	1) Provide necessary contact time and carbon energy source for buffering to take place 2) provide for longterm storage of nutrients in forest trees	Predominant vegetation composed of variety of native riparian tree and shrub species suitable to site and such plantings necessary for soil stabilization during establishment period	Management for wildlife, aesthetics, and timber are compatible with purpose as long as leaf litter, detritus, and large woody debris production and shade levels are maintained	Livestock presence discouraged except for designed streamcrossings (allowed only on small streams) and for designed watering facilities located outside the buffer or within the buffer (if the watering facility is fenced)	Periodic harvesting and timber stand improvement (TSI) with appropriate recommendations from state and federal forestry agencies are allowed and encouraged to maintain vigorous growth and to remove nutrients and pollutants stored in the timber		Limited to subsurface and shallow, uniform flow. Concentrated flow must be converted to subsurface or shallow, uniform flow prior to entering ZONE 2. Open ditches and subsurface drains crossing ZONE 2 are discouraged

* Select species adapted to soil and site and for their ability to achieve other benefits, such as wildlife habitat improvement. Consult with NRCS, FS, or FWS for species selection.
Native streamside species on HSG C and D and native upland species on HSG A and B.
Deciduous species are important for leaf litter C leachate production which drives bacterial processes and evergreens for potential nutrient uptake in winter months.
In regions receiving less than 20in annual precipitation or where the water table will not support trees, predominant vegetation may be a mixture of grass and shrubs.
Refer to State Standard and Specifications for Tree Planting and for Streambank and Shoreline Protection for specific requirements to establish, manage, and maintain trees.

** Management for wildlife habitat, aesthetics, and timber are compatible secondary objectives as long as their management does not jeopardize the primary function of the buffer.
Mechanical site preparation which exposes large amounts of bare soil, such as rootraking and windrowing, piling, disking, or bedding is prohibited.

*** Livestock presence is discouraged because of probable negative impacts such as livestock trails and vegetative damage; all of which limit buffer effectiveness in this zone.
Intensive management is necessary to prevent negative impacts if livestock are present in this zone. Lack of management or mismanagement will result in negative impacts.
Intensive management might include controlled, intensive, short term grazing when conditions are dry and firm and when serious vegetation damage will not occur???
On areas planted to grass, controlled, intensive grazing is allowed when conditions are dry and firm.
On areas planted to grass, grazing or hay harvesting can be used instead of mowing and removal of clippings to remove vegetative growth when conditions are dry and firm.

**** All forest harvesting operations shall be in compliance with State Standard and Specifications for Improved Harvesting and with recognized BMP's.
Stand density shall be maintained within 25% of forest density guidelines for forest type and size class

***** Such concentrated flows are discouraged because they shortcircuit the buffering effectiveness of the buffer.
Use of techniques such as grading and shaping and devices such as level lip spreaders can be used to encourage uniform flow.
These techniques and devices should be located in the outer zone to limit concentrated flow throughout the buffer.

ZONE 3							
WIDTH	PURPOSE	VEGETATION*	GENERAL MANAGEMENT	LIVESTOCK MANAGEMENT**	FORESTRY MANAGEMENT	WILDLIFE	FLOW REQUIREMENTS
20ft minimum width measured horizontally in the direction of flow (additional width may be desired to accommodate land shaping and mowing equipment). Ungrazed grassland meeting ZONE 3 purpose may serve as ZONE 3	Provide sediment filtering, nutrient uptake, and space necessary to convert concentrated flow to uniform, shallow, sheet flow through the use of techniques such as grading and shaping and devices such as diversions, basins, and level lip spreaders	Dense perennial grasses and forbs. Vegetation must be maintained in vigorous growth condition (may not be consistent with wildlife needs)	Mow and remove clippings to recycle nutrients, promote vigorous sod growth and control weeds. Inspect twice annually. May require periodic reshaping of earth structures, removal or grading of accumulated sediment, and reestablishment of vegetation	1) Controlled, intensive grazing, 2) grazing instead of mowing and removal of clipping to remove vegetative growth, and 3) hay harvesting are all allowed when conditions are dry and firm so that earth control structures and vegetation are not damaged		Attention should be given not to mow or harvest during nesting season.	Open ditches and subsurface drains crossing ZONE 3 are discouraged; however, drains may outlet water within ZONE 3 if the flow is converted to uniform flow upon outlet.
* Select species adapted to the soil and site and with ability to achieve other benefits such as forage production and wildlife habitat improvement							
Refer to Filter Strip Standard for seeding mixtures. Improved grass species are allowed.							
** Designed watering facilities should be located outside the buffer or within the buffer (only if the watering facility is fenced).							